2.8 Smiths Lake catchment description

Smiths Lake is a small coastal barrier lagoon situated approximately 25 km south of the township of Forster on the lower mid-north coast of New South Wales (Figure 2.8.1). The lake has a total catchment area of 35.89 km^2 and a total waterway area of approximately 10 km^2, physically divided into three similar-sized basins (Webb, McKeown & Associates 1998). The most easterly of the three basins is relatively shallow, averaging <1.0m, with substantial sand deposits surrounding the intermittently open entrance to the ocean. The middle and western basins are somewhat deeper drowned valleys averaging 2.4 m and 1.6 m deep, respectively (Webb, McKeown & Associates 2001). The Smiths Lake catchment falls wholly within the Great Lakes local government area.

The ocean entrance for Smiths Lake has been mechanically opened at regular intervals since 1932 to prevent inundation of low-lying properties, improve water quality or allow construction works along the lake foreshore (Webb, McKeown & Associates 1998, 2007). When open to the ocean, the lake is subject to the oceanic tidal regime, swell and currents. When closed to the ocean, the principal source of water flowing into the lake is from several small creek networks including Wamwarra and Tarbuck creeks (Figure 2.8.1).

The catchment has two broad topographical units: barrier dunes to the south, and sedimentary slopes to the north and west. Smiths Lake catchment soils are generally of low fertility: colluvial and aeolian soil landscapes are the most common within the catchment, dominating the inland slopes and coastal dunes, respectively.

The cultural heritage of Smiths Lake and its catchment includes a rich Aboriginal heritage, and significant land use changes under European settlement (see Appendix 16 for detail). The extent of vegetation and ecosystem modification attributable to Aboriginal land use within the catchment is difficult to quantify. However, the arrival of European settlement began a new and accelerated landscape modification. The earliest European land use was timber harvesting commencing in 1816, followed by commercial fishing in the late 1800s. The most significant land use change was urban development in the late 1960s when road improvements allowed greater access to the area. Although the steep and relatively infertile landscape has limited development across much of the catchment, several pockets of urban development have been established around the lake shores.

Today, the dominant land uses in the catchment are conservation, forested land, agriculture and urban development (Figure 2.8.2). The catchment remains relatively undeveloped, with urban and rural residential development only occupying 2.8 km^2. Approximately 30% (10.70 km^2) of the catchment is contained within Myall Lakes and

Wallingat national parks estate, and a further 32% (11.74 km^2) of the catchment remains forested – either under private ownership or within State forest estate. Commercial fishing remains the main economic activity in the catchment, with up to 11 commercial fishers on the lake throughout the year.

Discussion of the economic industries in the Smiths Lake catchment, and each land use type, are found in Appendix 16. This appendix also contains a description of land use change as well as the ecological significance of the Smiths Lake area. In undertaking analysis for this Plan, detailed land uses have been grouped into several broad classifications. These classes are based on the analysis of catchment model outputs, which showed similar generation rates of nutrients and sediments. Groupings used in the analysis are:

- **Forestry:** This group is comprised of: (1) Hardwood production, which is land managed for hardwood sawlogs or pulpwood; (2) Production forestry, which involves commercial production from native forests and related activities on public and private land; and (3) State forest.
- **Improved pasture:** This group is comprised of: (1) Pasture legume/grass mixture; (2) Irrigated sown grasses; and (3) Irrigated legume/grass mixture.
- **Native vegetation:** This group is comprised of: (1) Remnant native cover, which is land under native cover that is mainly unused (no prime use), or used for non-production or environmental purposes; and (2) Riparian vegetation.
- **Protected vegetation:** This group is comprised of: (1) National parks, which are protected areas managed mainly for ecosystem conservation and recreation; and (2) Strict nature reserves, which are protected areas managed mainly for science.
- **Unpaved roads:** All unpaved roads mapped for the Great Lakes catchments.
- **Unimproved pasture:** This land use type is native / exotic pasture mosaic, which is pasture with a substantial native species component despite extensive active modification or replacement of native vegetation (BRS 2006).
- **Rural residential:** This land use is "characterised by agriculture in a peri-urban setting, where agriculture does not provide the primary source of income" (BRS 2006).
- **Urban residential:** This group is comprised of: (1) Urban residential (e.g. houses, flats, hotels); and (2) Recreation, which includes parks, sports grounds, camping grounds, swimming pools, museums and places of worship (BRS 2006).

Other land uses, such as transport corridors, have been included in the land use mapping (Figure 2.8.2).

The groups and their Australian Land Use and Management (ALUM) classification (BRS 2006) are listed in Appendix 6.

The key urban centre is Smiths Lake village (population of 1,036 at 2006 census), with smaller outlying residential areas at Tarbuck Bay, Neranie and the lower Wamwarra Creek valley.

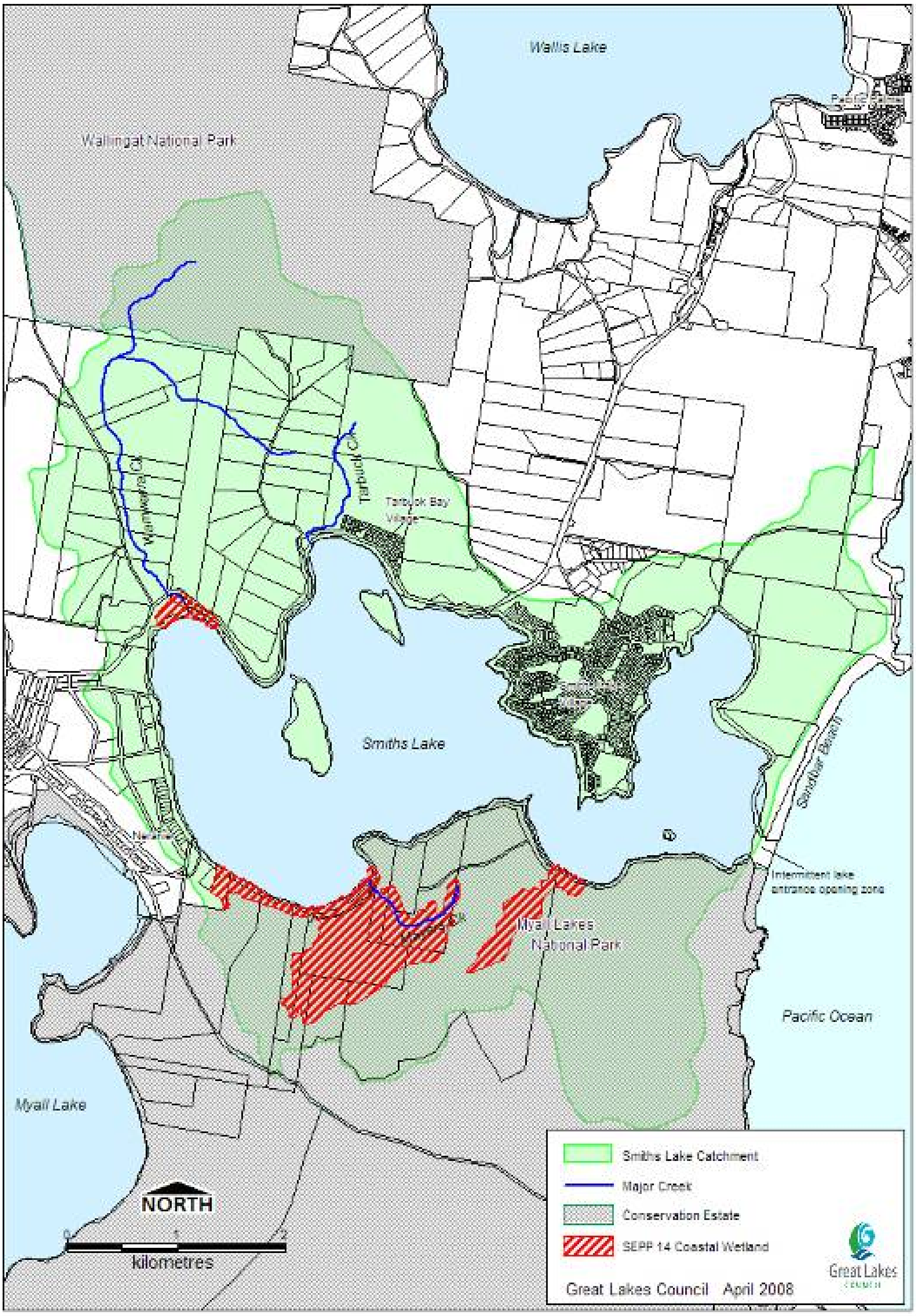


Figure 2.8.1. Smiths Lake catchment.

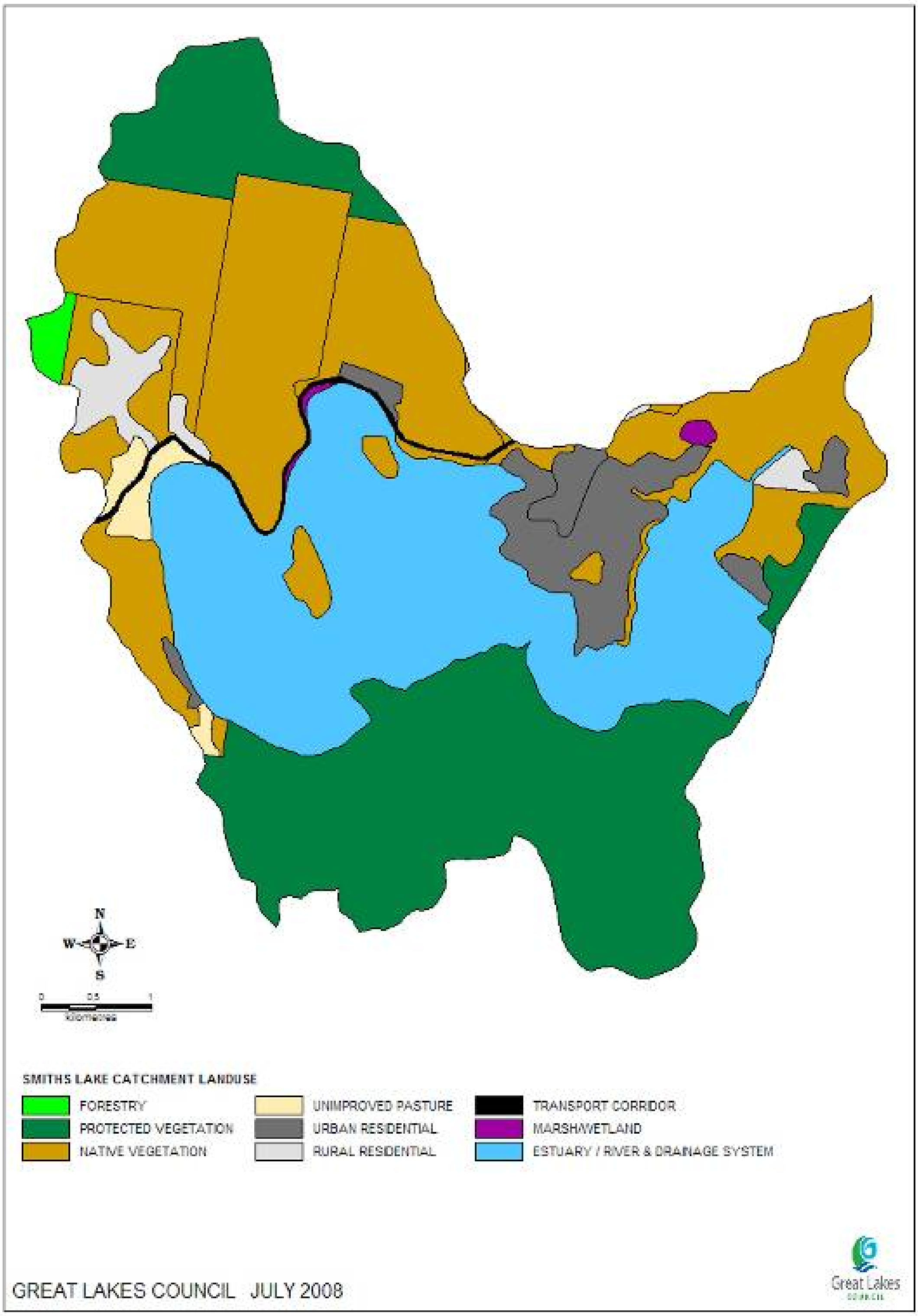


Figure 2.8.2. Modelled land uses in the Smiths Lake catchment. Please note the definitions for these land use categories are in Section 2.8.

The Smiths Lake catchment is an important ecological system, with a significant proportion of the catchment under conservation within the Wallingat and Myall lakes national parks, and the lake sectioned as part of the Port Stephens–Great Lakes Marine Park. There are three gazetted SEPP 14 coastal wetlands along the lake margins (Figure 2.8.1). A total of 16 vulnerable species of fauna have been identified in these habitat areas. As the lake is intermittently open to the ocean, it contains marine fish species that rely on the opening of the lake for spawning migrations and subsequent recruitment of juveniles.

Refer to Appendix 16 for further detail on the catchment topography, soils, history, land uses, urban development and the ecological significance (with respect to aquatic and terrestrial fauna and flora) of the Smiths Lake catchment.

The relatively steep and infertile nature of much of the Smiths Lake catchment has limited landscape clearing and modification. Compared to neighbouring Wallis and Myall catchments, little agricultural activity has occurred, so minimal catchment management activity has occurred away from the lake and urban areas.

Landcare groups have been active in the catchment since the early 1990s, with on-ground works involving weed control / removal and revegetation across 29 ha of urban bushland reserves, beach dunes and littoral rainforest communities. Great Lakes Council and the NSW government developed the Smiths Lake Estuary Management Plan (2001) to identify estuary management priorities and recommended on-ground works. The plan is supported by the actions identified in the Hunter-Central Rivers CMA Catchment Action Plan.

Due to the relatively undeveloped nature of the Smiths Lake catchment, little in the way of specific catchment management works has been completed away from the Smiths Lake village and Sandbar Beach area. Achievements to date include: 195.1 m of protective fencing to restrict stock access to revegetation or vegetation management areas; 10.8 ha of native vegetation or revegetation plantings under protective management; and 3,249 m^2 of erosion control measures completed on Tarbuck Park Road. Urban stormwater management in Smiths Lake village include two ski-jump gross pollutant traps, and a mixture of formal roadside kerb and guttering, grassed swales, table drains and modified natural watercourses. These programs are discussed in more detail in Section 3.2 and Appendix 16.

2.9 Smiths Lake – Current state of catchment and estuary health

2.9.1 Smiths Lake segments and rivers

Smiths Lake is a barrier lagoon system located approximately 25 km south of Forster on the NSW coast. It has a waterway area of 10 km^2, with a contributing catchment of 23 km^2. The lake entrance is predominantly closed but is artificially opened by the council to prevent flooding of low-lying areas.

The catchment has two main tributaries entering the lake in the north-west of the catchment: Wamwarra Creek and Tarbuck Creek (Figure 2.8.1).

2.9.2 Synthesis of research

2.9.2.1 Previous research

The research, modelling and monitoring completed through the Great Lakes CCI builds on the knowledge of catchment inputs and estuary processes developed through past projects. Key project reports are:

- Smiths Lake Water Quality Profiles (Manly Hydraulics Laboratory 1995[DG64])
- Smiths Lake Data Compilation Study (Geomarine 1996)
- Smiths Lake Estuary Management Study and Management Plan (Webb, McKeown & Associates 2001)
- Benthic Nutrient Fluxes in Smiths Lake NSW ([DG65]Smith & Heggie 2003)
- Biochemical analysis of Smiths Lake (Everett 2007).

2.9.2.2 CCI research

A component of the CCI project was to develop, verify and apply predictive models to quantify pollutant loads entering the Great Lakes waterways and the impact of these loads on ecological condition. The work focussed on the collection of relevant data on nutrient exports from specified land uses, effectiveness of management actions, nutrient cycling within stream networks, delivery to estuarine waters, and ecological and water quality implications within estuaries.

Specific tasks in the catchment modelling component included:

- estimating and collating contaminant (nitrogen and phosphorus) loads using catchment modelling techniques
- validating / refining model estimates through event-based water quality and flow measurements
- modelling effects of applying management practices within treatment trains (reduction of loads from catchments)
- developing and implementing case studies to refine catchment modelling parameters to estimate nutrient loadings.

Specific tasks in the ecological modelling component were to:

- determine the broad drivers and responses of the aquatic ecosystems
- develop hydrological / physical-chemical / ecological models for each lake to assess impact of contaminant loads from its catchment.

The broad drivers of the systems relate to nutrient and light availability. The responses of the aquatic system are related to the expansion and contraction of nuisance aquatic plants (e.g. phytoplankton blooms), and plants indicative of a healthy ecosystem (e.g. charophytes and seagrass).

2.9.2.3 Catchment management research

As part of the Great Lakes CCI project, research was undertaken by DECC Waters and Catchment Science and DPI on rural properties in the Wallis and Myall lakes catchments. Some of the findings from that research can be applied to the small area of agricultural land in the Smiths Lake catchment and are summarised in Section 2.5.2.3.

2.9.2.4 Urban catchment management research

No specific urban catchment management research was undertaken in the Smiths Lake catchment. Urban stormwater modelling was undertaken to identify appropriate management actions for the urban area of Smiths Lake and the recommendations are presented in Section 2.11.

2.9.2.5 Water quality in Smiths Lake

DECC Waters and Catchment Science undertook sampling in Smiths Lake in 2006/07. The data was used to develop an understanding of the ‘current’ conditions in the lake and, in conjunction with data from Everett (2007), used to calibrate the ecological model. Constituents sampled were:

- concentrations of all forms of nitrogen and phosphorus, turbidity, Secchi depth, light profiles, salinity and water temperature
- chlorophyll-a concentrations (a measure of the amount of phytoplankton [algae]) in the water).

Water clarity and chlorophyll-a concentrations are considered by DECC Waters and Catchment Science to be a more appropriate measure of ecological condition than water quality parameters, because they are direct measures of ecosystem status and recent studies have shown that they were the only indicators linked to catchment disturbance (Scanes, Coade, Doherty & Hill 2007[DG66]).

The WQIP uses abundance of microalgae (chlorophyll-a), water clarity (turbidity, Secchi depth) and the extent of seagrass as its primary indicators of estuary condition. Estuary Ecological Condition Targets (utilising trigger values) have been set for each of these indicators.

The results of this sampling have informed the assessment of ecological condition for Smiths Lake and are described in Section 2.9.3.

2.9.2.6 Ecology of Smiths Lake

Smiths Lake is a relatively undisturbed example of an intermittently open / closed coastal [DG67]lagoon. The largest natural influence on its ecology is its cycle of slowly filling and, when the ocean berm is breached, rapidly emptying a large proportion of its volume into the ocean. This cycle results in widely varying water depths and periods where much of the previously inundated lake margin is exposed for long periods before the entrance closes again. These patterns result in aquatic flora and fauna that is conditioned to change, and able to adapt rapidly to changes in water level. Smiths Lake has extensive seagrass beds, covering almost 30% of the lake's area. The low nutrient and sediment inputs, and the resulting clear waters, allow seagrass to penetrate to almost the maximum depth of the lake. The mostly intact foreshore vegetation and good ecological condition mean that Smiths Lake has high ecological value in the region.

2.9.3 Ecological condition

The *National Water Quality Management Strategy, Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000) is the basis for the majority of decisions about water quality management in NSW. ANZECC provides for three 'levels of protection' for aquatic ecosystems:

1. *High conservation value*: systems that have high ecological and / or conservation values, and are systems that are largely unmodified or have undergone little change.

They are often found within national parks, conservation reserves or inaccessible locations.

2. *Slightly to moderately disturbed*: systems that have undergone some changes but are not considered so degraded as to be highly disturbed. Aquatic biological diversity may have been affected to some degree but the natural communities are still largely intact and functioning.
3. *Highly disturbed*: systems that have undergone considerable degradation. Natural communities are largely not functional and nuisance species such as algae may be present in large volumes.

DECC has defined the typical features of lakes and coastal river estuaries according to the three levels of protection – *High conservation value*, *Moderately disturbed* and *Heavily impacted*. These categories are the equivalent of the levels of protection described by ANZECC above. DECC then identified where Smiths Lake fits in this scale (Appendix 10, Figure 2.9.1). Indicators of good ecosystem quality are high water clarity, low chlorophyll-a concentrations and very small amounts of green nuisance macroalgae among the seagrass.

This Plan focuses on chlorophyll-a concentrations as the primary ecological indicator because the estuary models were able to provide a link between catchment nutrient loads (expressed as total nitrogen (TN) inputs) and chlorophyll-a. Water clarity and turbidity are still considered to be useful indicators. However, for the purposes of this Plan, it is assumed that actions which control nutrient exports from catchments will usually also control sediments, and thus contribute positively to protecting water clarity and seagrass extent targets.

Indicator levels for chlorophyll-a concentrations that represent *High conservation value* or *Slightly to moderately disturbed* systems were defined by the Department of Environment and Climate Change (DECC) (Appendix 10). Table 2.9.1 shows mean chlorophyll-a concentrations measured across the lake by DECC Waters and Catchment Science in 2006/07 and identifies the order of change required to meet the indicator levels that would represent *High conservation value* and *Slightly to moderately disturbed*. Across Smiths Lake, chlorophyll-a concentrations ranged from 0.55 μg/L to 0.88 μg/L (average = 0.65μg/L), well below the trigger value identified for lakes that are considered pristine or of *High conservation value* status (1.8 μg/L). Turbidity was low (1.3 NTU) and Secchi depths appropriate. Together these indicators show the good ecological condition of the water body (Table 2.9.1).

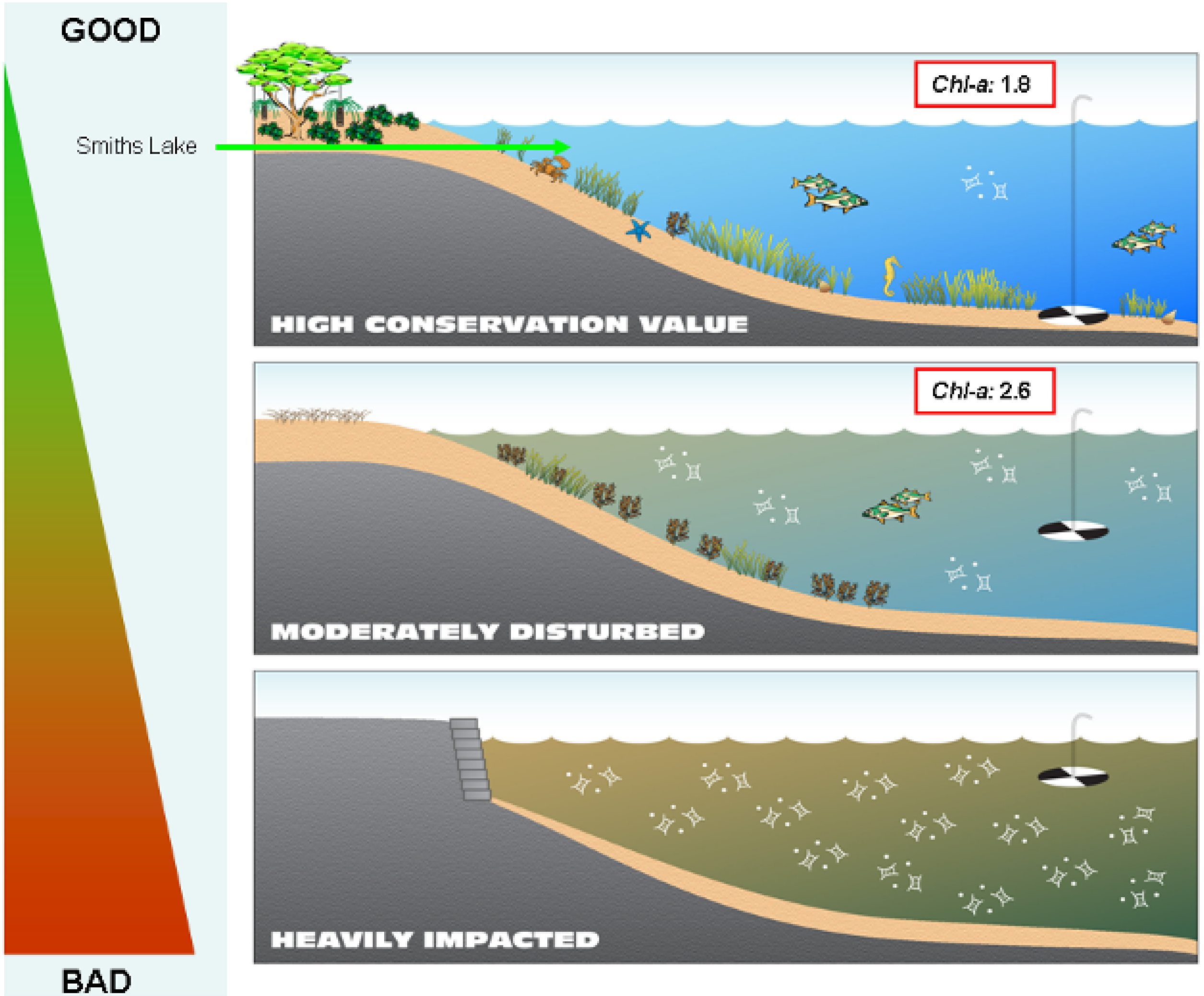


Figure 2.9.1. Current ecological condition of the coastal lake water body of Smiths Lake. Indicative levels of chlorophyll-a concentrations (µg/L) are shown as a range for *High conservation value* water bodies.

Table 2.9.1. Average chlorophyll-a concentrations (µg/L) and turbidity (NTU) recorded in Smiths Lake by DECC Waters and Catchment Science in 2006/07, and their relationship indicator levels representative of *High conservation value* and *Slightly to moderately disturbed* water bodies.

Smiths Lake	Measurements	High conservation value		Slightly to moderately disturbed	
		Level	Decrease to reach level (%)	Level	Decrease to reach level (%)
Chlorophyll-a	0.65	1.8	0	2.6	0
Turbidity	1.30	2.6	0	3.6	0

2.9.4 Hydrodynamics

The Smiths Lake hydrologic model describes how quantities (volumes) of water vary with time and how constituents (e.g. nutrients and sediments) are affected by different sources and losses. Influences to the model come from catchment inputs to the lakes, rainfall and exchange with the ocean. The entrance of the lake is considered to have three states:

- *closed entrance*: where the lake volume changes due to runoff volume from the catchment, direct rainfall and evaporation
- *open entrance*: where the lake volume changes due to runoff volume from the catchment, direct rainfall, evaporation and exchange with the ocean
- *overtopping*: where the lake volume changes due to runoff volume from the catchment, direct rainfall, and evaporation. This state differs from the closed entrance state in that as the water level rises above the barrier separating the lake from the ocean, water flows from the lake to the ocean. The water level remains constant but there is minimal tidal influence.

Smiths Lake shows large variation in water level depending on the status of the entrance. The photographs in Figure 2.9.2 demonstrate this, showing the impact of an entrance opening.

Figure 2.9.2. Response of Smiths Lake to an entrance opening. Top: 1pm, Day 0; Bottom: 1pm, Day 1 (Source: J. Everett).

The lake is usually well-mixed because the timescale for mixing in the lake is short (generally days to weeks) compared with the timescale between entrance openings (years) or major rainfall events (months). Salinity measurements by various researchers during 2002, but in particular Everett (2007), have shown the lake to be most often well-mixed both vertically and laterally. This is not to say that during infrequent periods of transition (after significant rainfall or after an entrance opening event) there will be periods of days to weeks when the lake will be heterogeneous (not well mixed).

2.9.5 Description of in-stream attenuation and remobilisation processes

There are few studies of in-stream nutrient attenuation and remobilisation processes in Australia. A description of in-stream nutrient attenuation and remobilisation processes, specific to the Great Lakes area, cannot be made without targeted experiments (e.g. nutrient uptake) and monitoring (e.g. discharge effects). This work was beyond the time and resources allocated for the CCI catchment and estuary modelling projects, although it has been recognised as a priority area for future research (Appendix 7).

There are not many streams in the Smiths Lake catchment. Due to the shortness and steepness of the streams, in-stream nutrient attenuation and remobilisation processes are not expected to be a dominant feature of the system.

2.9.6 Catchment loads and pollutant generation

Nutrient and / or sediment inputs to the hydrodynamic model come from sub-catchment inputs to the lakes, rainfall and exchange with the ocean. Estimates of the input on nitrogen from rainfall and the ocean were made from available data and were accounted for in the estuary modelling.

As part of the CCI, models of nutrient and sediment export from rural and urban lands have been developed for the Smiths Lake catchment area. The models allow the current loads of pollutants to be estimated as the projected loads under a range of land use and management scenarios.

The areas and current loads of sediment and nutrients being generated in the Smiths Lake catchment are given in Table 2.9.2.

Table 2.9.2. Area (ha) and nitrogen (kg), phosphorus (kg) and sediment (tonnes) loads for Smiths Lake sub-catchments.

Sub-catchment	Area (ha)	TN (kg)	TP (kg)	TSS (tonnes)
Smiths Lake	2,373	3,425	317	529

The relative contribution of different land use activities and sources of pollutants compared to the area they take in the sub-catchment is shown in Figure 2.9.3. Definitions of land use types can be found in Table 2.3.2. The accuracy of modelled outcomes is presented in Appendix 5.

Approximately 70% of the native vegetation and unpaved roads occur on high-slope (>20%) soils prone to erosion ('erodible'), with the remainder of these land uses occurring on low-slope erodible soils. Protected vegetation is split evenly between low and high-slope non-erodible soils. Half of the 14 hectares of unimproved pasture occurs on low-slope non-erodible lands, 33% on high-slope erodible and the remainder on low-slope erodible.

Roughly 86% of the catchment is forested. The bulk of the remaining land is unimproved pasture (~2%), urban (7%), rural residential (3%) and unpaved roads (1%).[10]

Urban areas and unpaved roads each account for about 30% of TN loads. Forest land contributes about 27% of the total catchment loads. Rural residential (4%) and unimproved pasture (8%) also contribute significant loads of TN.

Unpaved roads contribute proportionally less TP than TN (12%). Urban land contributes the most phosphorus (42%). Forest types account for another 40%. The remaining 6% of TP loads is sourced primarily from unimproved pasture.

Unpaved roads account for two-thirds of the TSS in the Smiths Lake catchment. Unimproved pasture and urban lands each contribute 12% of the total loads. Rural residential and forest land are relatively small contributors of TSS (4% and 5%, respectively).

This section identified the major sources of nutrients and sediment in the Smiths Lake catchment. The effectiveness of targeting these sources is discussed in Section 2.11.

10 These percentages vary slightly from those tabled in Appendix 16, as catchment exports for the land use class 'Water body' are not modelled in this Plan.

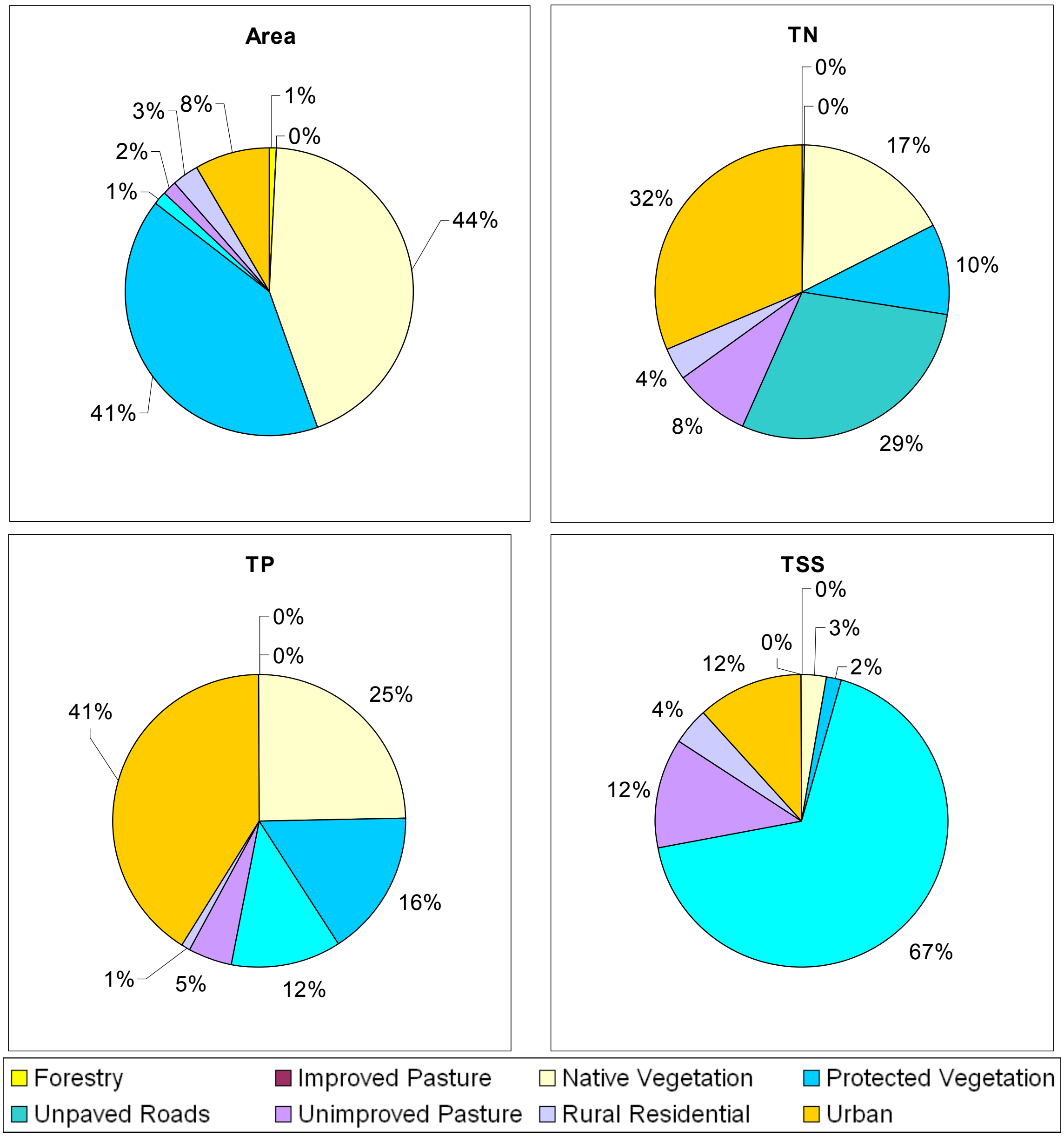


Figure 2.9.3. Relative contributions of land use activities to pollutants (TN, TP) and sediments (TSS) in the Smiths Lake catchment. For a description of land use categories used in the figure please see Section 2.8.

2.10 Smiths Lake – Setting targets for water quality management

2.10.1 Using community values to help set targets

In accordance with the *National Water Quality Management Strategy Guidelines* (ANZECC & ARMCANZ 2000), the following process shown in Figure 2.10.1 was utilised to develop water quality targets for Wallis, Smiths and Myall lakes.

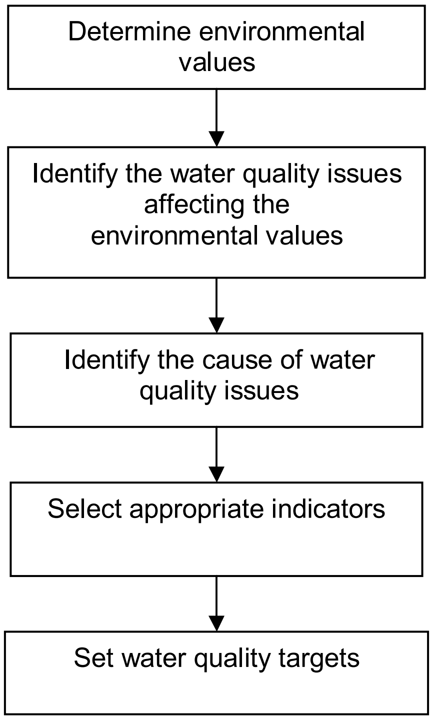


Figure 2.10.1. Process for developing water quality targets for Wallis, Smiths and Myall lakes (Source: Adapted from ANZECC & ARMCANZ 2000).

The first step in the process of identifying the environmental values, water quality issues and water quality targets for the local waterways involved checking that the existing values that had been set for the lakes by the NSW government in 1997 were still relevant. These environmental values were agreed by the community and endorsed by the NSW government.

Information on the existing environmental values for the various lakes (that were then subdivided into sub-catchment areas), and the intended process of reviewing these values with the Advisory Committee and community, can be found in *Environmental Values Background Report* (Great Lakes Council 2007a).

A workshop was held with the Advisory Committee to review the existing environmental values, and to make changes or additions. The results of this workshop are summarised in *Report on Environmental Value Setting by AC* (Great Lakes Council 2007b).

After trialling a similar workshop (to that held with the Advisory Committee) with the Wallis Lake Estuary Management Committee, it was decided to use a simpler and more accessible method for reviewing the environmental values with the community. Thus, a 'Recall Emotion Meaning Action' method was utilised in community workshops to ascertain how community groups value and use their waterways. This method and the process used at workshops – as well as the steps taken to involve industry groups and the community in reviewing the environmental values – is described in the Engagement Strategy and summarised in the Engagement Report (Appendix 1).

The activities, uses and important aspects of the waterways suggested by the participants were combined with the values set by the Advisory Committee. The resulting environmental values for Smiths Lake are presented in Table 2.10.1.

Table 2.10.1. Environmental values and uses given by stakeholders and the community for Smiths Lake.

Aquatic ecosystems	**Industry – Consump-tion**	**Primary recreation**	**Secondary recreation**	**Visual apprec.**	**Cultural**	**Group**
✓	✓	✓	✓	✓		Existing environmental values (EPA 1999)
✓	✓	✓	✓	✓	✓	Advisory Committee
✓		✓	✓	✓		Smiths Lake Landcare
✓		✓	✓	✓		Great Lakes Coastal Land mgrs network
✓	✓	✓	✓	✓	✓	Hunter-Central Rivers Aboriginal Cultural & Environmental Network (ACEN) – CMA Partnership Committee
		✓	✓	✓		Karuah / Great Lakes Landcare, Nabiac Landcare and Dyers Crossing Landcare
		✓	✓	✓		Forster U3A
✓	✓	✓	✓	✓	✓	**Summary of current values**

As shown in Table 2.10.1, aquatic ecosystems were valued by the community for Smiths Lake. The Framework for Marine and Estuarine Water Quality Protection: A Reference Document states that "where more than one environmental value applies to the same receiving waters, the environmental values need to be prioritised and the most stringent guideline should be used (ANZECC & ARMCANZ 2000). The most stringent guideline will in many cases also protect the other environmental values. In most cases, the water quality requirements for protection of aquatic ecosystems are the most stringent of all the environmental values." (Department of Environment and Heritage 2002, p. 13).

For this reason, water quality targets were developed to protect aquatic ecosystems and, by default, to protect the other values. The ANZECC Guidelines suggest that locally relevant environmental indicators are more useful than 'single number' guidelines that are applied universally. To derive locally relevant indicators to measure the health of aquatic ecosystems, scientific assessments of the local biological community were undertaken. These assessments worked out whether biological integrity is being maintained and determined local trigger values for the maintenance of this integrity. The locally relevant indicators that were determined were chlorophyll-a concentration, seagrass abundance and water clarity.

The local trigger values established were based on the aquatic ecosystem 'levels of protection'. Aquatic ecosystems can be protected to three different levels, depending on the current ecological condition of the ecosystems:

1. High conservation value
2. Slightly to moderately disturbed
3. Highly disturbed.

Figure 2.9.2 shows the current ecological condition of Smiths Lake relative to these categories. Details on these trigger values and how they were determined are outlined in Appendix 10.

Results from scientific research were used to determine the 'current' condition for each lake and potential target values for each indicator. Based on this research and the expectations of the community, the Advisory Committee selected an appropriate level of protection to aspire to and established *draft* Ecological Condition Targets for the indicators.

Possible management scenarios were tested with the DSS to ensure that targets were realistic and technically feasible. The agreed targets are documented in Section 2.10.2.

As mentioned previously, protecting aquatic ecosystems also protects many of the other values the community identified for Wallis, Smiths and Myall lakes. For example, water clarity is important for seagrass growth – and also to protect the recreational benefits of visual appreciation, primary and secondary recreation, and cultural values associated with natural areas.

The WQIP recognises that the chosen targets are not, alone, adequate to protect the values of human consumption (e.g. oysters). For this reason the WQIP reviews the systems that are in place to monitor and aim for targets in relation to faecal coliforms. An outline of these management systems and pollution control systems is provided in

Sections 3.5 and 3.7. The WQIP also makes a number of recommendations relating to the need to maintain and improve water quality management with respect to protection of human consumption values (Section 3.7).

2.10.2 Ecological Condition Targets and catchment loads

The Ecological Condition Target developed for Smiths Lake is to maintain the *High conservation value* of the lake, improving the ecological condition to establish a buffer and no deterioration. This section describes the community values and aspirations for setting this Ecological Condition Target, and considers this target in comparison to the feasible percentage reductions in chlorophyll-a concentrations modelled with implementation of the actions in this Plan (Table 2.10.1). Feasible percentage reductions in catchment loads are presented in Table 2.10.2.

Underlying this modelled information is an expert judgement on the degree and timing of uptake of different measures, the resources required for each program, and the effectiveness of actions (see Appendix 17 for details). These predictions provide an estimate of the change that will be experienced in seven years should the Plan be implemented in its entirety.

There is a degree of natural variability in relation to catchment loads and estuary concentrations of pollutants. These targets relate to the average annual load or mean concentration calculated over a long period. The way in which the targets have been formulated takes into account some of the natural variation expected in these environments (Appendix 10).

The targets are intended as triggers for action – in this context, if they are exceeded occasionally it is not of significant concern. However, if there is a sustained trend of exceedence then there would be a need to undertake further investigation and action. There may also be the potential to establish short-term ecological condition targets to be measured subsequent to rainfall events. This approach requires further investigation and consideration for future monitoring programs (Appendix 10).

The results in this section demonstrate the importance of protecting the lake against further deterioration. Remediation is very costly, time-consuming and is often limited in what can be achieved. Protection of areas of existing high value such as Smiths Lake is very important because the costs and limitations of remediation are such that any damage to these areas is likely to be irreversible. Likewise, further deterioration of modified areas of the lake is unacceptable to the community and is likely to be very difficult to reverse. Population pressures and other changes mean that some level of protection and remediation is required simply to maintain the current level of water quality without any expectation of improvement, even in areas that are currently damaged.

Smiths Lake should be managed to maintain its high conservation value. From discussions with the community and the Advisory Committee when setting environmental values (Section 2.10.1), the community and the Advisory committee indicated that they have zero tolerance for deterioration in the condition of the lake. They also indicated that they would prefer as much improvement in lake condition as is financially possible, even though the lake is currently in a very good condition. This improvement was seen as necessary to provide a buffer against possible unforeseen threats and future sources of pollution that may not have been accounted for in the modelling.

The consequences of a single erosion gully close to the lake on conditions in the Coomba Bay area of the Wallis Lake catchment emphasises the scale of risks that can stem from localised catchment management issues (see Wallis Lake case studies in Appendix 11). The southern end of Wallis Lake is in a similar condition to the Smiths Lake (when the lake entrance is closed) in that there is little exchange of water with the ocean and, consequently, the perimeter catchment strongly affects the water quality. In such situations, even seemingly minor failings in catchment management can have large, immediate and ongoing effects on the water quality and ecology of the lakes. The community and Advisory Committee expressed serious concern about the potential for events such as this to occur in the Smiths Lake and indicated a strong preference for preventative actions to be undertaken to reduce the risk of such occurrences.

Smiths Lake Ecological Condition Target: No deterioration. Improvements to establish buffer.

Ecological Condition Targets presented in this Plan are based on assumptions derived from discussions with community members and Council, as well as modelling and analysis. Ecological Condition Targets were defined for Smiths Lake by comparing monitoring data to chlorophyll-a concentrations indicative of *High conservation value*. Targets represent the percentage change required in chlorophyll-a concentrations to reach *High conservation value* (see Section 2.9.3). The monitoring data used to calculate the Ecological Condition Target is assumed to adequately represent the average condition of Smiths Lake.

Feasible reductions presented in Table 2.10.2 reflect the modelled reduction in chlorophyll-a concentrations achieved by implementing the modelled remediation actions described in Section 2.11.1. Underlying this information is an expert judgement on the degree and timing of uptake of different measures, the resources required for each program, and the effectiveness of actions. The Plan has been developed to guide water quality improvement actions for the next seven years. The Plan and associated modelling will be reviewed after six years and – allowing adequate time for this to occur – a revised Plan will be developed by year 7.

Table 2.10.2. Ecological Condition Target for Smiths Lake and the feasible reduction in chlorophyll-a concentrations.

	Ecological Condition Target	Feasible reduction in chlorophyll-a concentration (%)
Smiths Lake	No deterioration, improvements to establish buffer	3

Note: Smiths Lake is considered to have a *High conservation value*. This percentage reduction should be considered to be a buffer to maintain the current good condition of the lake.

This Ecological Condition Target implies a reduction in catchment loads for Smiths Lake. Decision Support Systems such as that used to develop this Plan have been demonstrated to be accurate in terms of the direction and magnitude of impacts. However, they are not assured as predictive models in the sense of accurately predicting precise future catchment export loads or resulting estuarine concentrations. In order to limit the effect of any such inaccuracies and produce the most accurate predictions of potential changes in loads and concentrations under the Plan, the magnitude and direction of change from the modelling has been used in conjunction with measured data (rather than modelled data) wherever possible to predict concentrations.

Feasible catchment load reductions for the Smiths Lake catchment are given in Table 2.10.3. These predicted load reductions correspond to the feasible reduction in chlorophyll-a concentration presented in Table 2.10.2. The modelled actions are discussed in Section 2.11.1.

Table 2.10.3. Feasible catchment load reductions in Smiths Lake that achieve predicted change in chlorophyll-a concentrations (Table 2.10.1).

Constituent	Current load	Seven-year load reduction (%)
TN (kg/year)	3,425	6.7
TP (kg/year)	317	7.3
TSS (tonnes/year)	529	2.7

2.11 Smiths Lake – Management strategies to achieve Ecological Condition Targets

The DSS developed as part of the Great Lakes CCI was used to conduct an exploratory analysis on the impact of potential rural and urban actions on nutrient and sediment exports into Smiths Lake and, as a consequence, changes in estuary concentrations. These changes were related to an Ecological Condition Target that was defined in Section 2.10.

Section 2.11.1 describes the results from the exploratory analysis of potential management actions for the Smiths Lake catchment. Analysis of costs and feasibility of actions was then undertaken to further refine the strategies recommended in the Plan. These recommended strategies are summarised in Section 2.11.2. A benefit-cost analysis of the Smiths Lake Plan is summarised in Section 2.11.3 and detailed in Appendix 15.

2.11.1 Exploratory analysis of potential remediation and protection actions

The Smiths Lake management strategies contain actions targeted to two specific purposes:

- to *remediate* existing areas of high pollutant loads, and thus provide reductions in catchment loads and estuary concentrations
- to *protect* areas of high conservation status that are currently providing substantial water quality benefits to the rivers and lake systems.

Protection actions are assumed in the Plan to not improve water quality, but rather to protect against further decline in water quality. The old adage – that it is cheaper to protect what is left than to replace it once it is gone – has been demonstrated to be true in this project with:

- the ongoing impacts from a localised gully in Coomba Bay (Appendix 11)
- the difficulty, indicated by CCI modelling, in returning disturbed parts of the Myall and Wallis Lakes back to *High conservation value* (e.g. Pipers Creek in Wallis Lake and Bombah Broadwater in Myall Lakes – see Sections 2.7.1 and 2.15.1, respectively).

These demonstrate the importance of protection actions as a key component of the Plan. Given the costs of remediation actions and the limits to their effectiveness at improving water quality at the catchment scale, it is essential that a range of protection actions – including protecting existing buffers and vegetation, and placing limits on inappropriate developments – are undertaken to ensure that water quality does not deteriorate in the lake.

It is often difficult to fully value the benefits of protection, as it can be difficult to estimate the damage that would be done without these actions taking place. By contrast, the effects (and benefits) of remediation actions are much easier to estimate.

Section 2.11.1.1 introduces the proposed remediation and protection actions for Smiths Lake. The DSS modelled the proposed remediation actions and their impact on catchment exports and estuary condition over a seven-year period. Many of the actions identified in the Plan are designed to be implemented over more than seven years (e.g. Wetland protection and Water Sensitive Development of Greenfield sites). In these cases, the impact at seven years assumes that implementation of these actions is in progress, rather than completed. For the purposes of the benefit-cost analysis (Appendix 15), the costs and benefits of these programs were estimated over a 30-year period. Details on the programs and associated costs are outlined in Appendix 17.

Sections 2.11.1.2 and 2.11.1.3 examine the modelled impact of remediation actions on catchment exports and subsequent estuary condition. Although the effect of individual protection actions could not be modelled in the DSS, an estimate of the impact of *not* implementing *all* protection actions recommended in this Plan is provided in Figures 2.11.1 and 2.11.2. This section discusses the results of two alternative futures – full implementation of the WQIP remediation and protection actions, or no implementation of protection actions and only the existing remediation actions from current programs.

Section 2.11.1.4 discusses the cumulative costs and cost-effectiveness of the modelled remediation actions.

2.11.1.1 Description of remediation and protection actions

Remediation actions modelled using the DSS for rural areas of the Smiths Lake catchment are shown in Table 2.11.1. Remediation actions can be:

- *existing programs*: works currently being implemented across the catchment (e.g. sustainable grazing programs focussed on achieving groundcover management actions). This Plan models existing programs as fully implemented in both the ‘No Plan’ and ‘WQIP’ alternative futures. Existing programs in the Smiths Lake catchment were minimal at the time of writing this Plan
- *expanded programs*: actions modelled and / or recommended in this Plan that will further reduce catchment export loads into Smiths Lake beyond that in the existing programs.

In order to estimate the benefits of these possible remediation actions, several scenarios were modelled and compared using the DSS. These essentially compared the implementation of these WQIP actions with the effects of current programs under the 'No Plan' alternative future.

Detailed descriptions of scenarios of existing and expanded remediation actions are provided in Appendix 17.

Table 2.11.1. Remediation actions modelled for rural areas of the Smiths Lake catchment.

Actions	Program description
Groundcover management	Groundcover management refers to a sustainable grazing program for landholders, and is focussed on improving groundcover management on pasture lands. It involves field days and formal workshops with experts, developing information and training material on stocking rates, formal training courses such as Prograze, a dung beetle release program, and a program of on-ground works that will assist landholders to better manage their groundcover levels (including off-stream watering, solar pumps and fencing).
Unpaved road remediation	This aims to identify and seal unpaved roads in priority areas, such as creek crossings. This would also include installing best practice sediment and erosion control features, such as mitre drains to divert road runoff into grassed areas.

For Smiths Lake, only groundcover scenarios were modelled due to there only being a small area of unimproved pasture to which rural remediation scenarios apply (and no improved pasture). The Myall and Wallis lakes plans consider a wider range of farm practices.

Remediation actions tested for urban areas of the Smiths Lake catchment are shown in Table 2.11.2. These involve retrofitting existing urban areas through implementation of Water Sensitive Urban Design (WSUD) devices. A description is included in Section 3.4.2.

Table 2.11.2. Remediation actions modelled for urban areas in the Smiths Lake catchment.

Actions	Program description
Urban Mitigation (Water Sensitive Urban Design)	Urban mitigation includes the retrofitting of rainwater tanks supported through a program of rebates. It is recommended that the tanks are plumbed into the home to maximise the water quality benefits. It also involves an extensive program of urban retrofitting where Water Sensitive Urban Design (WSUD) systems, such as biofiltration (including trenches, raingardens and biopods), are built into the existing urban landscape to filter the urban stormwater. This program also involves education and capacity-building on maintenance and construction of WSUD devices, adoption of a development control plan that specifies best practice Water Sensitive Urban Design, and associated staff training and capacity-building..

Protection actions considered for the Smiths Lake catchment are shown in Table 2.11.3. The individual impacts of not implementing these actions could not be modelled with the DSS. It is assumed that these actions all contribute to the avoidance of future deterioration. In order to estimate the effects of these 'protection' activities scenarios under the 'No Plan' situation, an estimate was made of the deterioration that would occur without recommended levels of protection being undertaken. It is recommended that these assumptions are reviewed as part of the seven-year review of the Plan and new estimates are made of the scale of protection necessary to avoid deterioration in water quality.

Detailed descriptions of the protection action scenarios are provided in Appendix 17, with urban actions detailed in Section 3.4.2.

Table 2.11.3. Protection actions considered for the Smiths Lake catchment. These actions were not modelled using the DSS.

Actions	Program description
Water Sensitive Development of Greenfield sites	Establish and implement LEP / DCP provisions on Greenfield development sites in the Smiths lake catchment to enforce 'no net increase' in pollutants relative to the existing land use (agricultural and forest land use classifications). This program also involves establishing heads of consideration for voluntary planning agreements with developers.
Best management of unpaved roads	Best management of unpaved roads includes construction of mitre drains to divert road runoff into grassed areas, and sealing and diversion of runoff away from streams particularly in the vicinity of creek crossings. This program involves mapping the location and extent of road erosion sites, and undertaking risk analysis in the catchment to prioritise roads for rehabilitation or closure. A program of training and auditing of contractors and council staff specific to road construction to ensure best management practices are applied will also be undertaken as part of this action.
Improved pollution control systems / management systems	Improved management and pollution control systems involves reviewing how water quality management, both within and between organisations, is approached. It focuses on establishing checking and review loops in key areas, such as compliance with conditions of consent, and sediment and erosion control. The program also highlights the need to embed water quality improvement actions in organisational plans to ensure the WQIP is implemented. It highlights the need to review a range of existing systems such as the fee structure for on-site sewage management, and recommends exploring alternative ways to formalise the response to complex pollution cases and strengthen cross-agency relationships and delegation.

Actions	Program description
Water Sensitive Redevelopment *	Water Sensitive Redevelopment involves the implementation of a development control plan that specifies best practice water-sensitive urban design (including biofiltration and rainwater tanks) on all redevelopments. The program of redevelopment has been estimated based on redevelopment rates in Forster. Therefore, this may be an over-estimation of improvements.
Improved management of lake use activities	Improved management of lake use activities involves supporting the actions related to seagrass protection as outlined in the Smiths Lake boating plan, reviewing stormwater management plans, and investigating other management options such as establishing markers to protect seagrass beds.

* Redevelopment was not modelled, as predicted redevelopment rates were low.

In this exploratory analysis, two alternative futures are considered:

- No Plan – no implementation of protection actions and only implementation of existing remediation actions
- WQIP – implementation of all protection actions and implementation of expanded remediation actions.

A trajectory of impacts over seven years is used to demonstrate the benefits of implementing protection and expanded remediation actions as part of the WQIP, compared with the current 'No Plan' condition as above. Many of the actions identified in the Plan are designed to be implemented over more than seven years (e.g. Wetland protection and Water Sensitive Development of Greenfield sites) – in these cases, the impact at seven years assumes that implementation of these actions is in progress, rather than completed[pt68]. The status of remediation and protection actions under these alternative futures at seven years is shown in Table 2.11.4.

Table 2.11.4. Scenario trajectories with (WQIP) and without (No Plan) the implementation of the Water Quality Improvement Plan for the Smiths Lake catchment. Existing programs refer to the full implementation of remediation actions planned and commence prior to the development of this Plan. Expanded programs were developed for this Plan to further reduce nutrient and sediment inputs into Smiths Lake, and are remediation actions. Both types of programs were modelled in this Plan. Protection actions were not modelled in this Plan.

[pt69]	Year 0	Year 7	
		No Plan	WQIP
Remediation actions			
Groundcover management	Existing situation	Existing programs	Expanded programs
Unpaved road remediation	Existing level	Existing level	Seven years of works
Urban Mitigation (Water Sensitive Urban Design)	Existing situation	None	Full implementation
Protection actions			
Water Sensitive Development of Greenfields	Existing situation	Seven years of development	Seven years of development
Water Sensitive Urban Design protection	Existing situation	Seven years without protection	Seven years with protection
Improved pollution control systems / management systems	Existing situation	Seven years without improved systems	Seven years with improved systems

2.11.1.2 Catchment exports

The percentage change in TN, TP and TSS loads for the entire Smiths Lake catchment in the ‘No Plan’ and ‘WQIP’ alternative futures as defined in Table 2.11.4 is shown in Figure 2.11.1. The ‘No Plan’ scenario incorporates a level of deterioration in the catchment that reflects a worsening of conditions if no protection actions or expanded remediation actions are taken over a seven-year trajectory.

For all pollutants, this deterioration is not halted by fully implementing existing rural remediation programs as these are very limited in the Smiths Lake catchment. The effectiveness of existing remediation programs is higher for TP and TSS than TN and, consequently, more TP and TSS is captured than by implementing existing remediation programs. Figure 2.11.1 shows that full implementation of protection actions and expanded remediation actions in the WQIP reduce catchment exports from current levels by 6.7% (TN), 7.3% (TP) and 2.7% (TSS) after seven years.

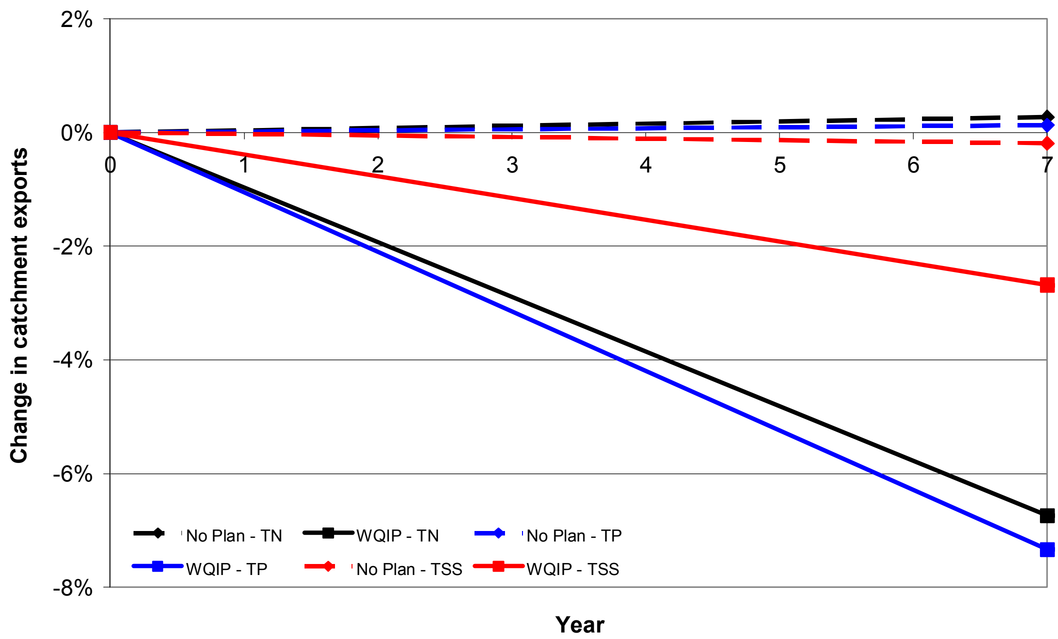


Figure 2.11.1. Percentage change in Smiths Lake catchment exports of TN, TP and TSS, both with (WQIP) and without (No Plan) implementation of the Water Quality Improvement Plan.

Figure 2.11.2 demonstrates the relative effectiveness of the modelled expanded remediation actions on pollutant exports for the Smiths Lake catchment. Implementation of WSUD devices largely account for reductions in TN and TP, although remediation of roads accounts for two-thirds of the catchment TSS load reductions. Urban development has no impact, as these lands are modelled assuming compliance with the ‘no net increase’ policy for development of Greenfield sites. The modelling examines the operational phase of Greenfield developments, and therefore does not account for construction phase impacts. However, these are likely to be confined to sediment with only minimal impact on nutrients, and are very much dependent on current erosion and sediment control programs being fully implemented within the Great Lakes Council region.

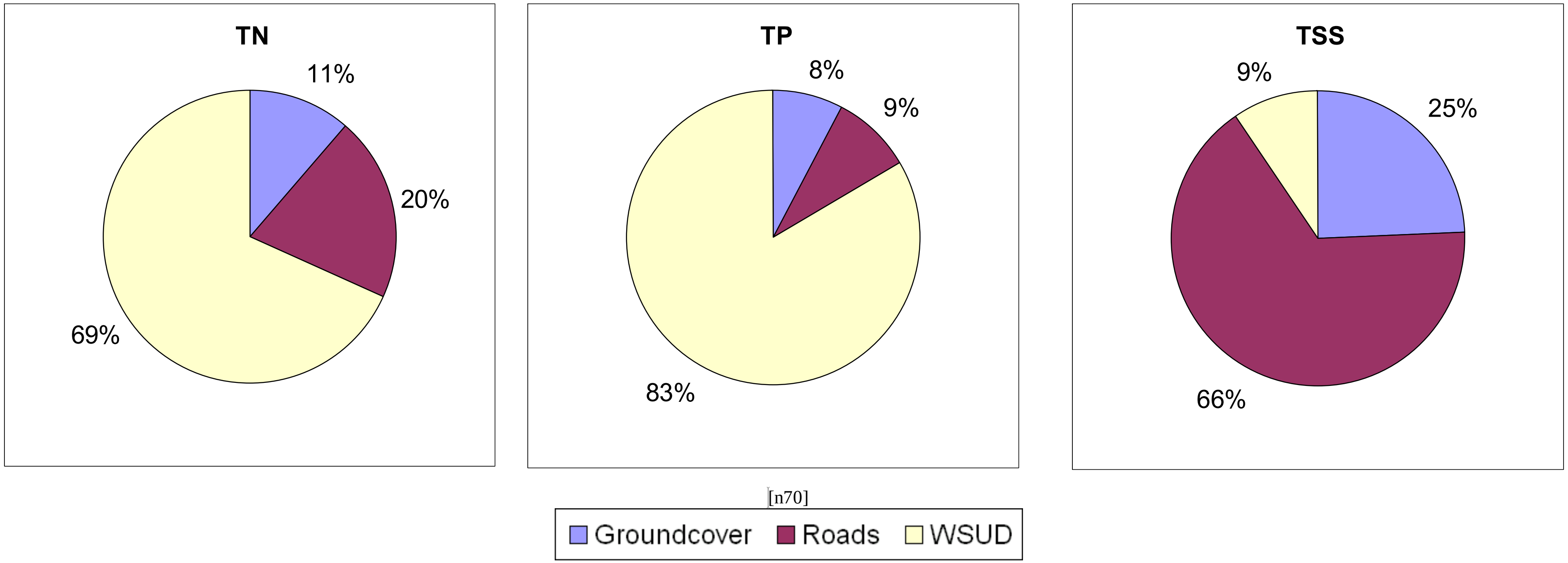


Figure 2.11.2. Relative modelled impact of expanded remediation actions for the Smiths Lake catchment with implementation of the WQIP. The % shows the proportion the remediation action contributes to overall reduction in catchment exports of nutrients and sediment.

2.11.1.3 Estuary condition

The estimated feasible change (in percentage reductions) in chlorophyll-a concentrations in Smiths Lake is shown in Figure 2.11.3. Reductions in chlorophyll-a concentrations of 3.6% are achieved in the lake with full implementation of the Plan. Small increases in concentrations are experienced if the Plan is not implemented.

Smiths Lake is already identified as *High conservation value*, so the decreasing chlorophyll-a concentrations, and hence improved ecological condition under implementation of the WQIP, will create a buffer to protect the ecology of the lake into the future. We would therefore not expect to observe changes to the current condition.

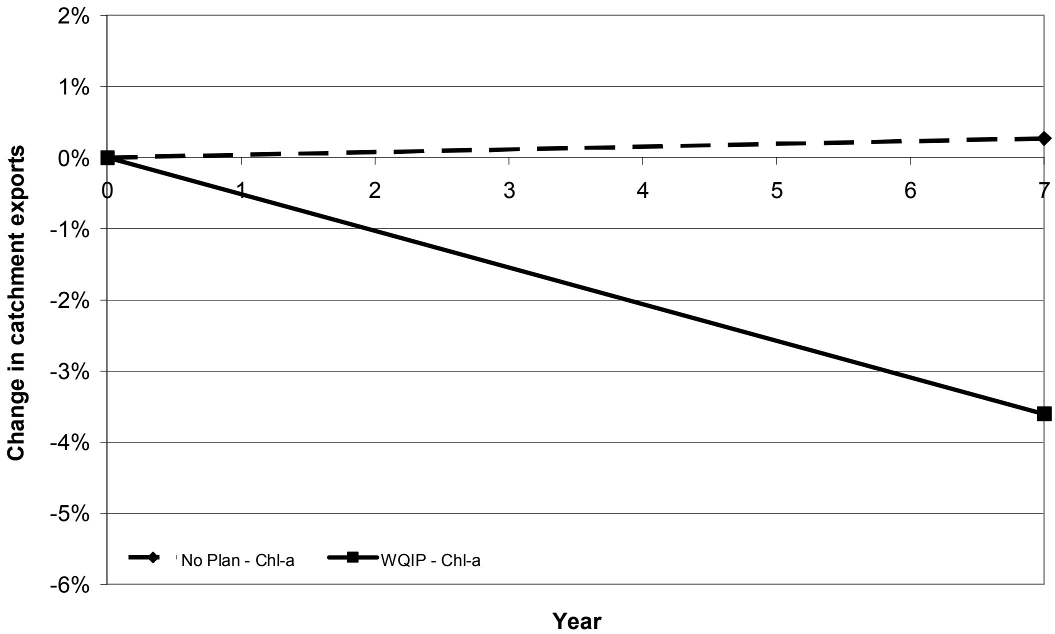


Figure 2.11.3. Percentage change in chlorophyll-a concentrations in Smiths Lake, both with (WQIP) and without (No Plan) implementation of the Water Quality Improvement Plan. A negative value indicates an improvement in conditions in the water body, as chlorophyll-a levels decrease.

2.11.1.4 Costs of rural and urban remediation actions

The cumulative costs of implementing and maintaining the modelled expanded remediation actions across the catchment over a seven-year trajectory are shown in Figure 2.11.4. Details of the assumptions used to define these figures are provided in Appendix 17. Implementation of urban mitigation is the most expensive action overall. Groundcover is the cheapest option.

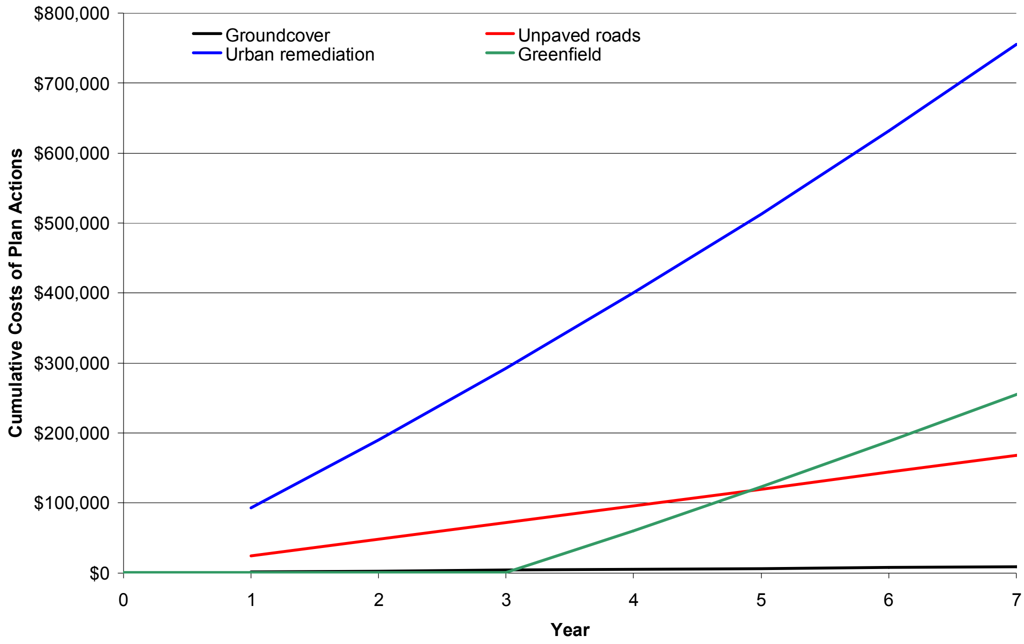


Figure 2.11.4. Cumulative costs of Plan actions in Smiths Lake.

Even though the overall costs of urban mitigation are shown to be the highest, the cost per unit of load of catchment export controlled by each action in Table 2.11.5 illustrates that these programs are a cost-effective means of reducing nutrient loads. However, the program is not as effective with respect to TSS. Roads are the least cost-effective for nutrients, as they have a large cost to implement and maintain. They are also relatively costly for controlling sediments. The groundcover program is a lower overall cost method of reducing both nutrient and sediment loads in the catchment, but has a limited overall capacity to control loads given the relatively small area of pasture lands in the catchment.

Table 2.11.5. Cost ($) per unit of load controlled by modelled remediation actions applied across the Smiths Lake catchment. A unit is 1 kg for TN and TP, and 1 tonne for TSS.

	Groundcover management	Unpaved road remediation	WSUD implementation
TN	$342	$3,615	$1,196
TP	$5,024	$80,895	$9,728
TSS	$2,553	$17,811	$139,226

The costs analysed above consider only those remediation actions that were modelled using the DSS. For actions that were not modelled, the costs and benefits of implementing the actions are summarised in Section 2.11.3.

2.11.2 Summary of recommended programs for protection, remediation and management support of Smiths Lake

A brief description of the programs recommended as part of this Plan for protection, remediation and management support of the Smiths Lake catchment are described in Table 2.11.6. Management support programs are those recommended to support the implementation of protection and remediation actions in the Smiths Lake Plan, and include adaptive management strategies, ecological monitoring and future investigations relating to the Farm Scale Action Plan. Management support actions do not lead themselves to having their impacts estimated using biophysical models and so have not been modelled in the DSS.

The resources required and activities to be undertaken as part of these remediation, protection and management support programs are also summarised in Table 2.11.6. Full details of assumptions behind these recommendations are given in Appendix 17, and more detail on the farm-scale actions that underpin the programs described is outlined in Section 3.3.

Note that it is recommended that the rural programs described below should be considered in the 'whole farm approach' described in Section 3.3 (and not implemented in isolation).

Responsibilities for implementing these programs are detailed in Section 3 of the Water Quality Improvement Plan.

Table 2.11.6. Summary of recommended programs in the Smiths Lake catchment: Protection, remediation and management support.

Program	Program description	Resources	Details
Remediation activities – modelled using DSS			
Groundcover management	Groundcover management refers to a sustainable grazing program for landholders, and is focussed on improving groundcover management on pasture lands. It involves field days and formal workshops with experts, developing information and training material on stocking rates, formal training courses such as Prograze, a dung beetle release program, and a program of on-ground works that will assist landholders to better manage their groundcover levels (including off-stream watering, solar pumps and fencing).	• Proportional allocation of resources based on catchment unit area and equivalent resources in the Myall and Wallis Lakes • Landholder training courses • Field days • Workshops • Dung beetle release • Provision of off-stream water and fencing	Section 3.3.2, Appendix 17
Urban Mitigation (Water Sensitive Urban Design)	Urban mitigation includes the retrofitting of rainwater tanks supported through a program of rebates. It is recommended that the tanks are plumbed into the home to maximise the water quality benefits. It also involves an extensive program of urban retrofitting where Water Sensitive Urban Design systems, such as biofiltration (including trenches, raingardens and biopods), are built into the existing urban landscape to filter the urban stormwater. This program also involves education and capacity-building on maintenance and construction of WSUD devices, adoption of a development control plan that specifies best practice Water Sensitive Urban Design, and associated staff training and capacity-building.	• Staff time (various amounts depending on year of program) to deliver capacity-building and auditing programs to implement DCP – Costs of new WSUD devices based on predicted redevelopment rates • Cost of retrofitting water tanks	Section 3.4.2, Appendix 17
Unpaved road remediation	This aims to identify and seal unpaved roads in priority areas, such as creek crossings. This would also include installing best practice sediment and erosion control features, such as mitre drains to divert road runoff into grassed areas.	• Cost of road sealing, and best practice sediment and erosion features • Treatment of 280 m of road in identified high-risk locations	Section 3.3.2, Appendix 17

Protection activities – estimate of combined effect of protection programs estimated based on past degradation. No split of impacts between actions able to be provided. This was not modelled using the DSS.			
Water Sensitive Development of Greenfield sites	Water Sensitive Development of Greenfield sites involves establishing and implementing LEP / DCP provisions on Greenfield development sites in the Smiths Lake catchment. This will involve enforcing 'no net increase' in pollutants relative to the existing land use (agricultural and forest land use classifications). This program also involves establishing heads of consideration for voluntary planning agreements with developers.[11]	• Acquisition and annual maintenance costs for WSUD devices • Staff and consultant time to implement programs proportional to the size of the urban area	Section 3.4.2, Appendix 17
Water Sensitive Urban Design protection [pt71]	WSUD protection is an education and capacity-building program on Water Sensitive Urban Design and management of urban land. It involves workshops, field days and demonstration sites with stakeholders including the general community, business, building and development industries. It involves updating plans, strategies and design guidelines (such as road guidelines), as well as resourcing a sediment and erosion control audit and training program.	• Council staff to deliver education and capacity-building programs, including training and audits proportional to the size of the urban area	Section 3.4.2, Appendix 17
Water Sensitive Redevelopment	Water Sensitive Redevelopment involves the implementation of a development control plan that specifies best practice Water Sensitive Urban Design (including biofiltration and rainwater tanks) on all redevelopments. The program of redevelopment has been estimated based on existing redevelopment rates.	• Costs of new WSUD devices based on predicted redevelopment rates and cost of maintenance	Section 3.4.2, Appendix 17
Foreshore and riparian management in urban areas	Foreshore and riparian management in urban areas involves improving foreshore areas around Wallis and Smiths lakes through establishing site-specific management plans, education and engagement of residents surrounding foreshore areas to reduce the impact of their behaviours, and increased enforcement of environmental legislation in these areas.	• Council staff to develop management plans and undertake community engagement	Section 3.4.2, Appendix 14

11 The modelling examines the operational phase of Greenfield developments, and therefore does not account for construction phase impacts. However, these are likely to be confined to sediment, with only minimal impact on nutrients, and are very much dependent on current erosion and sediment control programs being fully implemented within the Great Lakes Council region.

Best management of unpaved roads	Best management of unpaved roads includes construction of mitre drains to divert road runoff into grassed areas, and sealing and diversion of runoff away from streams particularly in the vicinity of creek crossings. The program involves mapping the location and extent of road erosion sites, and undertaking risk analysis in each sub-catchment to prioritise roads for rehabilitation or closure. A program of training and auditing of contractors and council staff specific to road construction to ensure best management practices are applied will also be undertaken as part of this action.	• Staff and consultant time for training and education program • Note this program does not cover the cost of undertaking best practice, as they are covered with routine road maintenance	Section 3.3.3
Improved management of lake use activities	Improved management of lake use activities involves supporting the actions related to seagrass protection as outlined in the Smiths Lake boating plan, reviewing stormwater management plans, and investigating other management options such as establishing markers to protect seagrass beds.	• Staff and consultant time • On-ground works	Section 3.5.2, Appendix 17
Improved pollution control systems / management systems	Improved management and pollution control systems involves reviewing how water quality management, both within and between organisations, is approached. It focuses on establishing checking and review loops in key areas, such as compliance with conditions of consent and sediment and erosion control, and also highlights the need to embed water quality improvement actions in organisational plans to ensure the WQIP is implemented. It highlights the need to review a range of existing systems such as the fee structure for on-site sewage management, and recommends exploring alternative ways to formalise the response to complex pollution cases and strengthen cross-agency relationships and delegation.	• Council and state government agency staff time • Costs of development of GIS-based data base • All costs proportional to the catchment area	Section 3.7, Appendix 17
Management support actions – not modelled in the DSS			
Adaptive Management Strategy / Ecological monitoring program	The Adaptive Management Strategy underpins the implementation of the WQIP. It highlights the ecological, political and social uncertainties surrounding the WQIP, and identifies ways to track these and make informed management decisions during plan implementation. The ecological monitoring program outlined in the strategy involves the collection of data on ecological indicators such as chlorophyll-a, water clarity, habitat assessments on river reaches and fish sampling. The strategy also recommends a public reporting regime for the WQIP.	• Council staff time to do the reporting and collating for the WQIP, proportional to the catchment area • Specialist assistance for establishing the WQIP monitoring program – Staff time • Equipment hire	Section 3.9, Appendix 30

Future investigation relating to the Farm Scale Action Plan[DG72]	Specific areas for future investigation that relate to improving farm management practices are undertaken through this program. Areas for investigation include riparian management, wetland management, groundcover management, farm infrastructure management, nutrient management and ways to encourage uptake of improved management practices. The findings from this research are applicable across all three catchments (Wallis, Smiths and Myall lakes).	• Researcher and specialist time proportional to the rural area	Section 3.3.2

Total costs of the Smiths Lake management actions identified for protection, remediation and management support are summarised in Table 2.11.7. These costs assume full implementation of all actions over the seven-year period.

Table 2.11.7. Summary of total costs at seven years of remediation, protection and management support actions for Smiths Lake catchment as recommended by the Plan.

Action	Cost at seven years
Remediation action	
Groundcover management	$9,000
Urban Mitigation (Water Sensitive Urban Design)	$756,000
Unpaved road remediation	$168,000
Protection action	
Water Sensitive Redevelopment	*
Water Sensitive Development of Greenfield sites	$188,000
Water Sensitive Urban Design protection	$1,500[pt73]
Foreshore and riparian management in urban areas	$38,000
Best management of unpaved roads	$3,700[pt74]
Improved management of lake use activities	$35,000
Pollution control systems	$2,000
Management support action	
Adaptive Management Strategy	$1,000
Ecological monitoring	$5,000
Future investigation relating to the Farm Scale Action Plan	$14,000
Total	**$1,221,200**[DG75]

* It is predicted that the redevelopment rates at Smiths Lake will be low, and have therefore not been costed here.

The management actions for the Smiths Lake catchment costs in total approximately $1.2 million over seven years. Note that no discounting has been used to account for costs incurred in later years. This means that the net present value of these costs is less than is shown here. This table shows that protection actions placing restrictions on Greenfield development, and implementing WSUD protection and pollution control systems, cost less than remediation actions such as WSUD implementation or unpaved road management.

2.11.3. Summary of benefit-cost analysis results for the Smiths Lake Plan

Gillespie Economics conducted a benefit-cost analysis for the Smiths Lake management actions. To undertake this type of analysis it was necessary to cost the implementation of the plan over a 30-year period. While the plan does not present the 30-year figures, this section is intended to provide indicative benefit cost for future implementation. This section summarises the results of this analysis. Table 2.11.8 lists the potential costs and benefits identified in the analysis of the implementation of the Smiths Lake Plan.[12] Full details of assumptions made and methods used for estimates of the benefit-cost results presented here can be found in Appendix 15. The actual costs associated with the identified programs are detailed in Appendix 17.

Table 2.11.8. Costs and benefits for the Smiths Lake management actions.

Costs	Benefits
Direct program costs	***Direct program benefits***
• Groundcover management	• Improvements in estuary health
• Unpaved road remediation	• Improvements in river health
• Greenfield	• Increased native vegetation conservation
• Water Sensitive Urban Design protection[pt76]	• Benefits to commercial recreation
• Pollution control systems	• Benefits to commercial fishers
• Adaptive Management Strategy	• Benefits to non-market recreation
• Ecological monitoring	• Benefits to urban amenity
• Future investigation relating to the Farm Scale Action Plan	
• Urban Mitigation (Water Sensitive Urban Design)	
Indirect program costs	***Indirect program benefits***
• Opportunity costs of riparian revegetation and protection	• Reduced fertiliser costs and increased productivity of agricultural land
• Costs of alternative water supplies where dams are eliminated	• Increased agricultural productivity where dams are eliminated

Two decision criteria for assessing the economic desirability of a project to society were considered in this analysis:

- *Net present value*: the sum of the discounted benefits less the sum of the discounted costs. A positive net present value indicates that it would be desirable from an economic perspective for society to allocate resources to the project, because the community as a whole would obtain net benefits from the project

12 Protection actions for unpaved roads were not included as part of the benefit-cost analysis.

- *Benefit-cost ratio*: the sum of discounted benefits divided by the sum of discounted costs. A benefit-cost ratio greater than 1 indicates that the investment is economically efficient and hence desirable from an economic perspective.

Calculations of both net present value and benefit-cost ratio indicate that the Plan is **not** economically efficient and desirable from a community perspective (Appendix 15). Table 2.11.9 shows that the total benefit-cost ratio for implementation of the Smiths Lake management actions is 0.2. Benefit-cost ratios above 1 are considered to be positive. This also shows that the Plan is difficult to justify on the grounds of economic efficiency.

As described in Section 2.11.1.3, the modelling undertaken to develop this WQIP has focussed on the ecological response of the estuary in relation to changes in catchment loads. Recognising that there is a suite of benefits that cannot be accounted for in this approach (including the improvements that occur on individual river reaches), economic analysis of individual management actions was undertaken to partially account for this limitation. The benefit-cost ratios for individual actions in the Smiths Lake Plan are shown in Table 2.11.9.

Table 2.11.9. Smiths Lake WQIP benefit-cost ratio of individual actions[pt77]**.**

Program	Benefit-cost ratio
Remediation actions	
Groundcover management	2.4
Unpaved road remediation	0.0
Water Sensitive Redevelopment	0.8
Urban Mitigation (Water Sensitive Urban Design)	0.8
Protection actions	
Water Sensitive Development of Greenfield sites	*
Water Sensitive Urban Design protection	*
Foreshore and riparian management in urban areas	*
Best management of unpaved roads	*
Improved management of lake use activities	*
Improved pollution control systems / management systems	*
Management support actions	
Adaptive Management Strategy / Ecological monitoring	*
General awareness-raising and business planning	*
Future investigation relating to the Farm Scale Action Plan	*
Total	**0.2**

* The benefit-cost ratio was not calculated for these programs. Refer to Appendix 15 for further information.

This data facilitates consideration of which action is providing the greatest return on investment, as represented by the benefit-cost ratio. Allocation of benefits to each individual action in the WQIP was achieved by estimating the contribution that each action makes to general water quality improvement in the estuary and allocating benefits associated with water quality improvement, accordingly. Non-water quality benefits including vegetation conservation, wetland benefits and changes to river health were also allocated to the relevant WQIP action.

The analysis indicates that the majority of Smiths Lake management actions **do not** provide a positive return on investment (Table 2.11.9). Groundcover management provides a positive return on investment, largely as a result of agricultural productivity improvements. All other actions have costs exceeding their benefits. The method applied to estimate the physical changes associated with protection actions (Greenfield and WSUD protection) was very coarse and is likely to have biased the results towards showing smaller, rather than larger, benefits in Smiths Lake, given it is based on historical rates of degradation in the catchment (which is currently relatively undisturbed). A more detailed analysis of potential degradation under alternative development scenarios might give a better estimate of the benefits of these actions, and so should be considered.

Overall these results show that the benefit-cost analysis is unable to provide evidence to support the economic efficiency of the Smiths Lake Plan. This is largely because Smiths Lake is currently in a *High conservation value* condition and predicted changes in water quality under the Plan actions do not lead to any benefits that are able to be estimated. An attempt has been made to estimate the possible deterioration of the lake without the Plan. However, it is likely that this underestimates the true deterioration that may occur without protective actions being undertaken. It is also very difficult to account for the possibilities of low-probability, high-consequence events that may affect Smiths Lake without adequate protection. Coomba Bay provides a stark example of the damage that can be caused in a single event from a failure to adequately protect against these types of events. For this reason, while the benefit-cost analysis for Smiths Lake raises questions about the economic efficiency of the Smiths Lake Plan, it is seen to be important to go ahead with the Plan as proposed in order to manage these difficult to account for risks. Future studies should focus on identification of potential risks, and evaluation of the costs and benefits associated with managing for these.

2.12 Myall Lakes system and catchment description

The Myall Lakes system is situated on the NSW Lower Mid North Coast, approximately 30 km north of Port Stephens (Figure 2.12.1). The lakes have a total catchment area of 780 km^2 and total waterway area of 102 km^2. The Myall Lakes system is a coastal barrier lake system of four linearly interconnected brackish to freshwater basins: Myall Lake, Boolambayte Lake, Two Mile Lake and Bombah Broadwater. Average depth of the system is 2.7 m, although connecting channels reach up to 13 m in depth. The Myall Lakes catchment can be divided into six sub-catchments: Upper Myall River, Lower Myall River, Crawford River, Bombah Broadwater, Boolambayte Creek and the Myall Lake catchment area (Figure 2.12.1), with additional flows from immediate surrounds of the lakes – an area of approximately 263 km^2. The Lower Myall River estuary has a minor influence on the ecological condition of the Myall Lakes, as there is an average net outflow of water from Bombah Broadwater into the Lower Myall River and limited tidal exchange to the area[DG78].

The Myall Lakes catchment has three broad topographical units: sedimentary / metamorphic inland ridges and valleys; floodplain; and a coastal sand dune system. Soils are generally of low fertility: colluvial and erosional soil landscapes are the most common within the catchment, dominating the inland undulating slopes and drainage lines.

The cultural heritage of Myall Lakes and their catchment includes a rich Aboriginal heritage, and significant land use changes and development of industry under European settlement. The extent of vegetation and ecosystem modification attributable to Aboriginal land use is difficult to quantify. However, the arrival of European settlement led to a major alteration in catchment land use. Timber harvesting began in the catchment in 1816, and expanded with timber grants in the 1830s for use in the ship-building industries down the Myall River at Port Stephens and on to Newcastle. Clearing of forest opened the area for cattle grazing, and with improved pasture species of rye and clover, the dairy industry followed. Despite this clearing, substantial tracts of native vegetation remain in the catchment, conserved as national park, or managed by State Forests or private landholders.

Today, the dominant land use in the Myall Lakes catchment is conservation, encompassing approximately 45% of the catchment, including the lakes themselves (Figure 2.12.2). State Forest and private native forest (multiple land uses) cover a further 38% of the catchment. Grazing lands cover 14% of the catchment. Beef grazing is now replacing dairy as the primary agricultural land use within the Myall Lakes catchment.

Commercial fishing activities are carried out on the waters of the Myall Lakes, the Lower Myall River and on the eastern beaches of the barrier dune complex (NPWS 2002).

Discussion of the economic industries in the Myall Lakes catchment and each of the land use types are found in Appendix 18. In undertaking analysis for this Plan, detailed land uses have been grouped into several broader classifications. These classes are based on similar generation rates. Groupings used in the analysis are:

- **Forestry:** This group is comprised of: (1) Hardwood production, which is land managed for hardwood sawlogs or pulpwood; (2) Production forestry, which involves commercial production from native forests, and related activities on public and private land; and (3) State forest.
- **Improved pasture:** This group is comprised of: (1) Pasture legume/grass mixture; (2) Irrigated sown grasses; and (3) Irrigated legume/grass mixture.
- **Native vegetation:** This group is comprised of: (1) Remnant native cover, which is land under native cover that is mainly unused (no prime use), or used for non-production or environmental purposes; and (2) Riparian vegetation.
- **Protected vegetation:** This group is comprised of: (1) National parks, which are protected areas managed mainly for ecosystem conservation and recreation; and (2) Strict nature reserves, which are protected areas managed mainly for science.
- **Unpaved roads:** All unpaved roads mapped for the Great Lakes catchments.
- **Unimproved pasture:** This land use type is native/exotic pasture mosaic, which is pasture with a substantial native species component despite extensive active modification or replacement of native vegetation (BRS 2006).
- **Rural residential:** This land use is “characterised by agriculture in a peri-urban setting, where agriculture does not provide the primary source of income” (BRS 2006).
- **Urban residential:** This group is comprised of: (1) Urban residential (e.g. houses, flats, hotels); and (2) Recreation, which include parks, sports grounds, camping grounds, swimming pools, museums and places of worship (BRS 2006).

The groups and their Australian Land Use and Management (ALUM) classification (BRS 2006) are listed in Appendix 18. More details on features of these land uses can be accessed from http://adl.brs.gov.au/mapserv/landuse/alum_classification.html (Sourced: 24 July 2008).

Urban and rural residential development covers 10.35 km^2 (1.3%) of the catchment, supporting a population of 2,010 (at 2006 census). The largest township is Bulahdelah (population 1,161), with additional villages of Nerong (150 houses) and parts of Bungwahl village on the northern shore of Myall Lake (see Figure 2.12.1 for locations). There are several rural residential subdivisions in the Myall River and Boolambayte Creek sub-catchments.

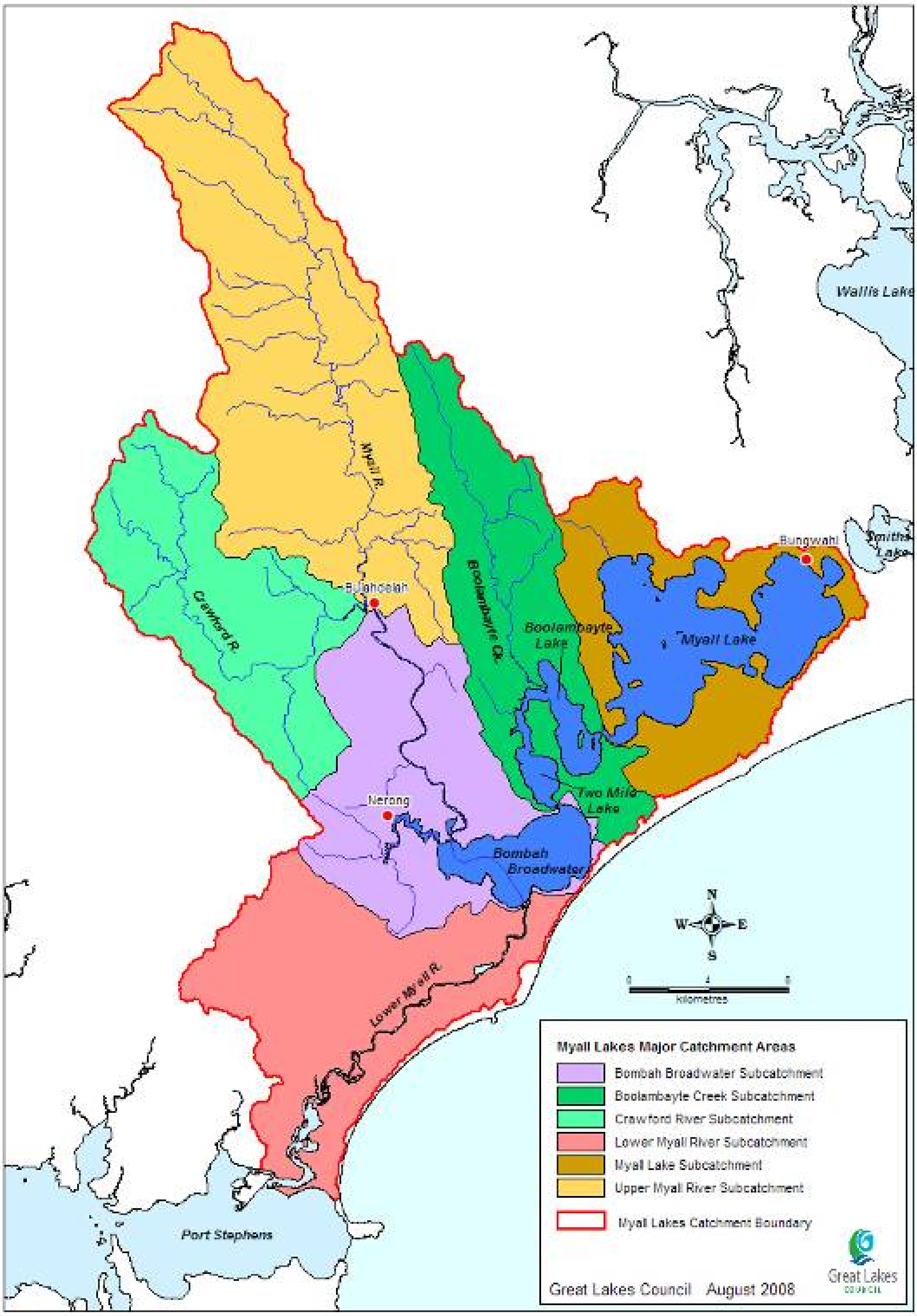


Figure 2.12.1. The Myall Lakes sub-catchments and major tributaries.

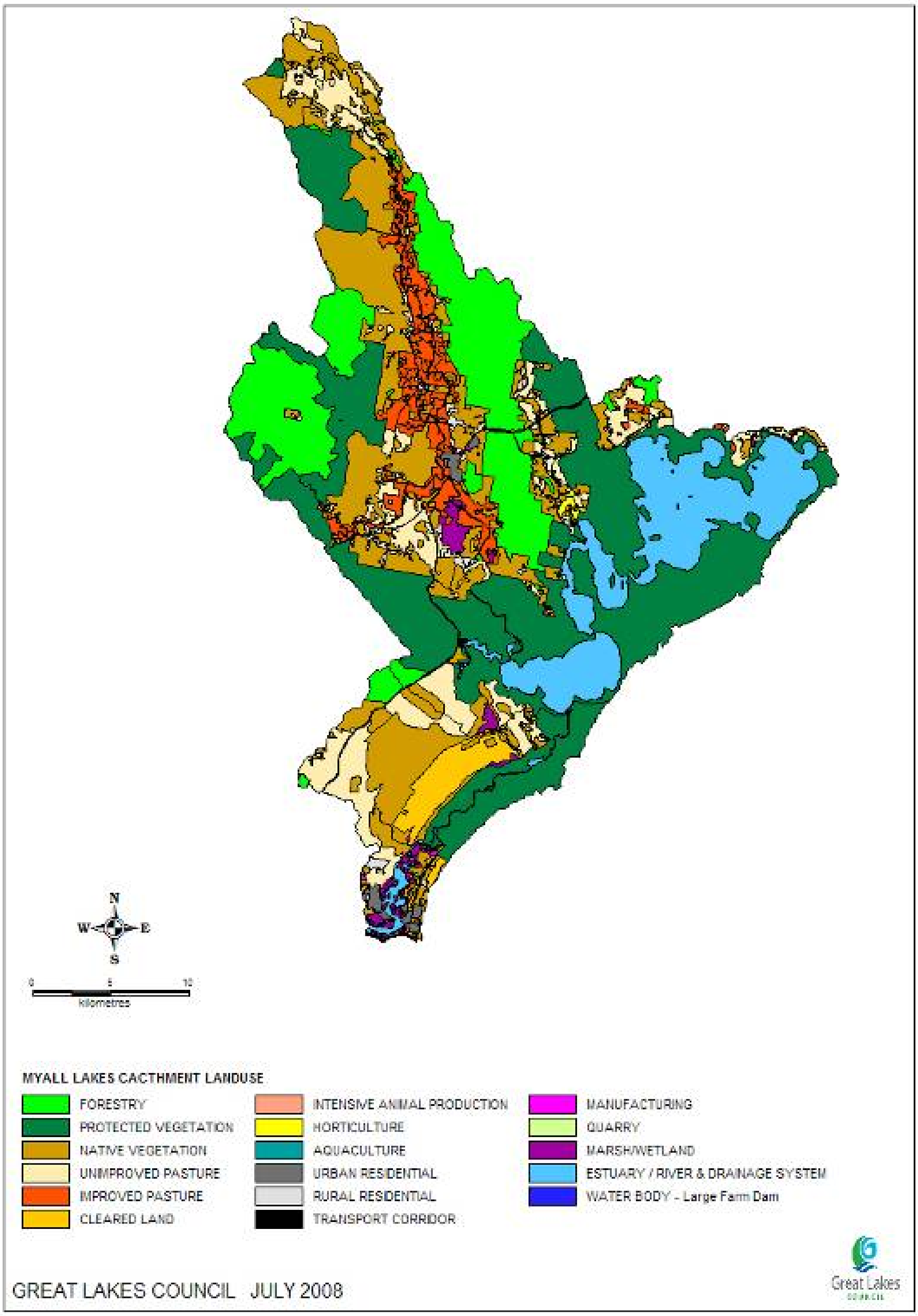


Figure 2.12.2. Modelled land use categories in the Myall Lakes catchment. Definitions for these land use categories are described in Section 2.12.

The Myall Lakes and catchment is an important ecological system, with the lakes classified as *High conservation value*, and protected within the Myall Lakes National Park and the Port Stephens–Great Lakes Marine Park. The Myall Lakes National Park is listed as a Ramsar Wetland of International Importance, and provides habitat for an estimated 25 JAMBA and CAMBA-listed international migratory bird species (NPWS 2002). The margins of the lakes hold protected coastal wetlands and provide habitat for a range of threatened species listed on the *Threatened Species Conservation Act 1995*. The catchment supports a diverse range of vegetation communities including sub-tropical rainforest, mixed *Eucalyptus* spp. forest, woodland, coastal dry and wet heath, grassland, and wetlands (i.e. swamp, swamp forest, wet heath and fringe forest).

The Myall Lakes catchment has localised gully and stream bank erosion, and eutrophication of creeks and waterbodies, which remain significant management issues today. Landcare was introduced to the catchment in the early 1990s, and since the late 1990s, landholders have been increasingly encouraged by the Great Lakes Council and industry groups (such as Mid Coast Dairy Advancement Group) to participate in federal, state and regional programs to improve on-farm management.

Following a toxic blue-green algal bloom in 1999, the Great Lakes Council and State Government developed *The Myall Catchment: Community Catchment Management Plan* (Smith 2001). The plan details strategies capable of achieving catchment management objectives and is supported by the actions identified in the *Hunter-Central Rivers CMA Catchment Action Plan*. The *Rivercare Plan and Companion Booklet* (2000[DG79]) and *Port Stephens / Myall Lakes Estuary Management Plan* (2002)[DG80] provide similar recommendations for on-ground works.

At the time of writing this report, very few of the recommended strategies have been implemented at a catchment-wide scale. Valuable land management projects have been completed on 11 sites in the Myall Lakes catchment, but generally there has been limited landcare or specific catchment management activity. Achievements to date include: 3.81 km of protective fencing to control stock access to waterways and vegetation management areas; two off-stream stock watering systems; 6.5 ha of native revegetation; 29,960 m^2 of stream bank erosion control measures; and three dairy sheds modified for effluent management. Urban stormwater works include stormwater litter baskets to intercept urban street litter within Bulahdelah.

2.13. Myall Lakes – Current state of catchment and estuary health

2.13.1. Myall Lakes segments and rivers

The Myall Lakes system consists of four interlinked water bodies that probably originally had ecologies that were fundamentally similar, but differed in detail due to the effects of salinity. The water bodies are (in order of increasing salinity exposure): Myall Lake, Boolambayte Lake, Two Mile Lake and Bombah Broadwater. The Myall River upstream of the Broadwater is similar in form to other Middle to Upper River estuaries (refer to Section 2.3.3). Figure 2.13.1 shows the Myall Lakes system, with the four interlinked lake water bodies and major tributaries of Crawford and Myall rivers, and Boolambayte Creek.

Condition in the Myall Lakes is reported in this Plan for three zones (Figure 2.13.1):

- Myall Lake
- Boolambayte Lake and Two-Mile Lake (referred to as Boolambayte Lake)
- Bombah Broadwater.

Condition in the river estuary for the Myall Lakes system is reported in this Plan for the Upper Myall River estuary (Figure 2.13.1). The condition of the Lower Myall River is not reported in this Plan.

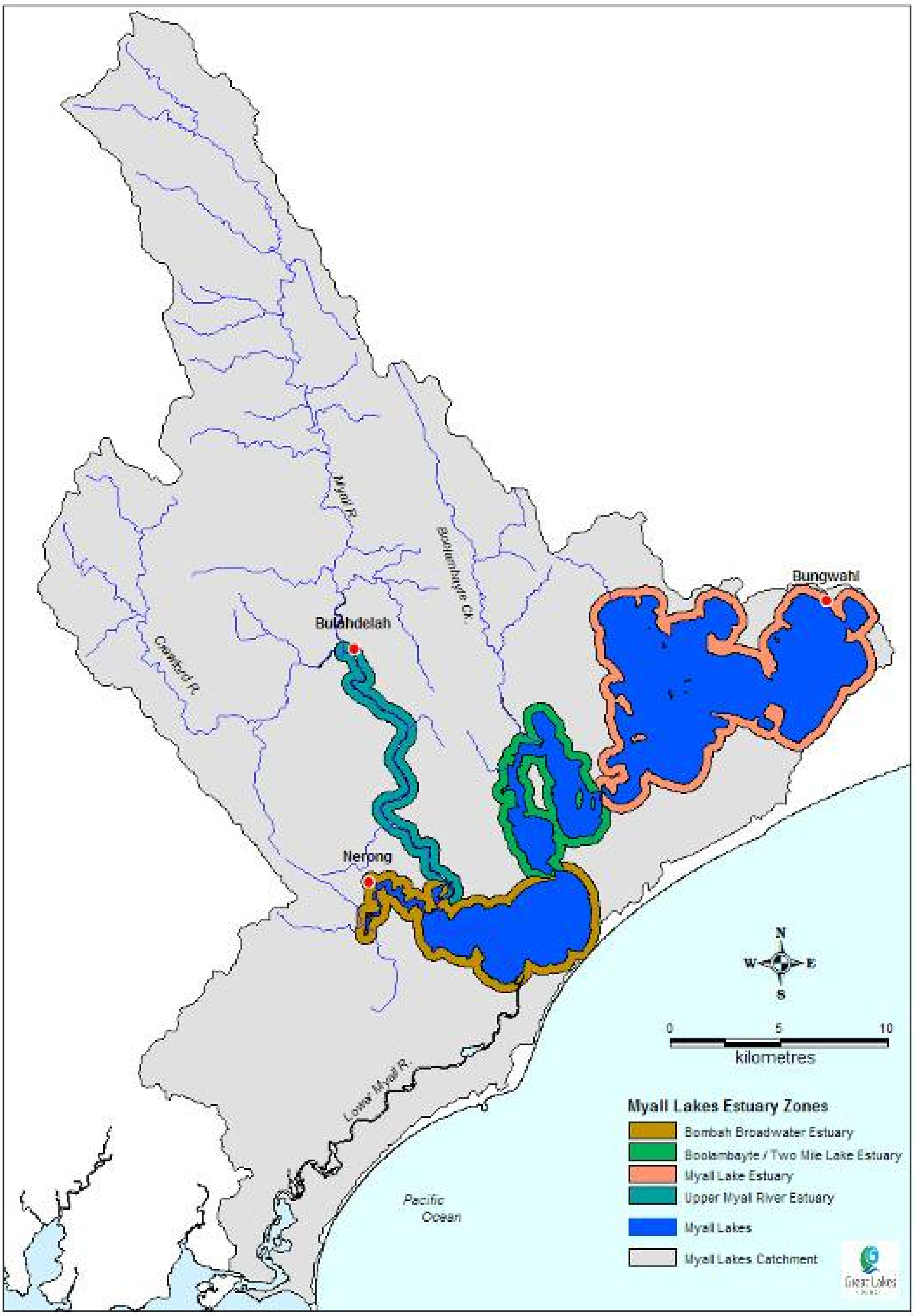


Figure 2.13.1. Zones in Myall Lakes system used for modelling and analysis, and reporting on condition in this Plan.

2.13.2. Synthesis of research

2.13.2.1 Previous research

The Myall Lakes and its rivers have been subject to many years of water quality and ecological research and monitoring. Projects have ranged from agency water quality sampling in the creeks and lakes to detailed research into the ecological processes driving the patterns in algal blooms within the Myall Lakes. Projects such as these have helped to build our understanding of estuary processes and catchment inputs.

The research, modelling and monitoring completed through the Great Lakes CCI builds on the knowledge of catchment inputs and estuary processes developed through past projects. Key projects are:

- Description of the physio-chemical water characteristics, and the distributions of macrophytes and algae (Dasey *et al*. 2004)
- Benthic fluxes of nutrients from sediments (Palmer, Fredericks, Smith & Heggie 2000)
- Distribution of charophyte species (Asaeda, Rajapakse & Sanderson 2007)
- Ecology and chemistry of Myall Lakes (Wilson 2004)
- Calculating flow into coastal lakes from water level measurements (Sanderson & Baginska 2007)
- Aspects of nutrient cycling (e.g. Shilla, Asaeda, Fujino & Sanderson 2006)
- Description of the physio-chemical water characteristics, and the distributions of macrophytes and algae (Dasey *et al*. 2004)
- Port Stephens / Myall Lakes Estuary Process Study ([DG81]Department of Public Works 1999)
- An ecological investigation of the Myall Lakes region (Atkinson, Hutchings, Johnson, Johnson & Melville 1981)
- Understanding blue-green algae blooms in Myall Lakes NSW (Dasey *et al*. 2004)
- An investigation of the factors leading to cyanobacteria bloom development and succession in Myall Lakes April 1999 – April 2001 (Ryan 2002). Graduate Diploma in Natural Resources thesis, University of New England, Armidale, NSW.
- Myall Lakes National Park, Little Broughton Island and Stormpetrel Nature Reserves Plan of Management (NPWS 2002)
- Investigations into the taxonomy, toxicity and ecology of benthic cyanobacterial accumulations in Myall Lake, Australia. *Marine and Freshwater Research*, vol. 56, pp. 45–55 (Dasey *et al*. 2005[DG82]).
- Port Stephens and Myall Lakes Estuary Management Plan (Umwelt 2000)

- Bulahdelah, Hawks Nest and Tea Gardens Stormwater Management Plan (Jelliffe 2000)
- Coastal Lake Management Strategy Myall Lakes (Wilson 2006).

The CCI research described here further links water quality changes in the catchment to the ecological response of the estuary. Details are outlined in the following section.

2.13.2.2 CCI research

A component of the CCI project was to develop, verify and apply predictive models to quantify pollutant loads entering the Great Lakes waterways and the impact of these loads on ecological condition. The work focussed on the collection of relevant data on nutrient exports from specified land uses, effectiveness of management actions, nutrient cycling within stream networks, delivery to estuarine waters, and ecological and water quality implications within estuaries. DECC Waters and Catchment Science undertook catchment modelling and estuary modelling, while BMT WBM developed detailed models of urban areas and pollutant treatments.

Specific tasks in the catchment modelling component of the CCI included:

- estimating and collating contaminant (nitrogen and phosphorus) loads using catchment modelling techniques
- validating / refining model estimates through event-based water quality and flow measurements
- modelling effects of applying management practices (reduction of loads from catchments)
- developing and implementing case studies to refine catchment modelling parameters to estimate nutrient loadings.

Specific tasks in the ecological modelling component were to:

- determine the broad drivers and responses of the aquatic ecosystems
- quantify nutrient cycling between estuary waters and sediments
- develop hydrological / physical-chemical / ecological models for each lake to assess the impact of contaminant loads from its catchment.

The broad drivers of the lake systems relate to nutrient and light availability. The response of the aquatic ecosystem depends on the expansion and contraction of nuisance aquatic plants (e.g. phytoplankton blooms), and plants indicative of a healthy ecosystem (e.g. charophytes and seagrass).

2.13.2.3 Catchment management research

DECC Waters and Catchment Science undertook monitoring of two types of management practices that are currently implemented on farming properties in the Great Lakes area – riparian fencing and off-stream watering – and compared them to properties that had not implemented either management practice. Properties where these actions had not been implemented had a greater proportional area of bare soil along the stream banks. While the monitoring data showed no discernable differences in the water quality (nutrient and sediment concentrations) of streams, it showed distinct differences in the biological condition of the streams (Haine, Dela-Cruz & Scanes in prep).

Properties that implemented off-stream watering and / or riparian fencing had a greater number of species and abundance of fish than those that had not implemented such a management practice. Streams on properties with riparian fencing also had greater overall diversity of fish than those without riparian fencing or off-stream watering. The difference in fish assemblages is due to improved stream habitat condition (i.e. more twigs and leaves, and trailing vegetation) which, in turn, is due to greater and better cover of vegetation along the stream banks (Haine, Dela-Cruz & Scanes in prep.).

A rural management practice project was undertaken by the Department of Primary Industries to provide a basis for developing policy, strategy and ultimately projects that will reduce the impact of rural land use on water quality within the Great Lakes CCI. The project was undertaken in three parts:

1. A literature review of the processes and management of sediments, nitrogen, phosphorus and faecal pathogens to provide a basis for assessing a wide range of strategies available to farmers.
2. A survey of on-farm practices and conditions that may pose a risk to water quality. This was undertaken at two levels: an on-farm assessment of the three major industries – poultry (3), beef (6) and dairy (4); and a wider survey of 44 beef farms, the largest industry by farm number, to gain a more representative sample.
3. A brief simulation study of runoff, leaching and nitrate movement using Dairymod™.

The findings of this project are outlined in *Rural Management Practice Final Report* (in prep)[DG83]. The main findings and recommendations are:

- Soil erosion, principal stream and gully erosion are the main sources of sediments and nutrients, and present the greatest threat during big rain events.
- Greatest funding needs to go to restoring riparian vegetation in a targeted way. A better result will be achieved by targeting high-risk areas rather than simply targeting willing farmers.

- Low groundcover after drought remains a threat. Drought strategies that are applicable to this area need to be further developed. Some issues are difficult to reconcile, i.e. the cost of grain feeding is high on the coast, and the definition of a drought is unclear.
- Inappropriate fertiliser use in agriculture can contribute nutrients such as phosphorous from superphosphate – therefore, fertilisers need to be applied appropriately.
- Dairy and poultry industries in the CCI area are higher nutrient users and need more intensive measures. However, they are small in area, i.e. less than 1% of the catchments. Support needs to be given to current industry lead programs to help farmers use best practice solutions.
- The issues associated with the concentrated use of poultry manure could be minimised by subsidising the transport and cost of chicken litter. This would assist with its wider distribution – so that it is not concentrated around the chicken sheds – and applied using best management practice guidelines. More industry negotiation and stakeholder engagement is required.
- Poultry litter should be applied according to the Department of Primary Industries best management practice guidelines.
- Farmer adoption is a key, thus programs should consider the whole farm needs, and facilitate both productivity and water quality outcomes.

2.13.2.4 Urban catchment management research

No specific urban catchment management research was undertaken in the Myall Lakes catchment. Research relevant to the Myall Lakes was undertaken in the Wallis Lake catchment and is detailed in the Wallis Lake Plan (Section 2.5.2.4).

2.13.2.5 Water quality in the Myall Lakes

Water clarity and chlorophyll-a concentrations are considered by DECC to be the most appropriate measure of ecological condition rather than water quality parameters, because they are direct measures of ecosystem status. Recent studies have shown that they were the only indicators linked to catchment disturbance (Scanes *et al*. 2007[DG84]).

It is well accepted in the literature that intensification of land use and removal of native vegetation leads to increases in the amount of nutrients and sediments washed down rivers to estuaries. The nutrients stimulate the growth of algae in estuaries (both microalgae in the water, and slimes and weeds around the lake edge) and the sediments reduce water clarity, resulting in reduced light to bottom-living plants such as seagrasses. In extreme conditions, the amount of algae in the water can significantly reduce water clarity as well. Chlorophyll-a is the main pigment present in all plants, including the microscopic algae that occur in all waterways, and provides a convenient means of estimating the amount of invisible microalgae in water samples. It is expressed as the concentration of the chlorophyll pigment per volume of water (i.e. μg/L). Turbidity is a measure of the amount of light scattered by particles in the water and is expressed as dimensionless 'nephelometric turbidity units' abbreviated as 'NTU'. Secchi depth is a measure of light transmission through water, and is affected by particles in the water and by water colour. It is made by lowering a standard black-and-white disk into the water and measuring the depth at which it becomes invisible to an observer above the disk.

Scanes *et al*. (2007) sampled 30 estuaries with differing amounts of catchment disturbance, and showed that chlorophyll-a concentrations and measures of water clarity were the best indicators of the effects of catchment disturbance on estuary condition.

Increases in the amount of algae and decreases in water clarity are early indicators that disruption to estuarine ecology is occurring. These disruptions could lead to harmful algal blooms, loss of habitat, reduced fish and seagrass abundance, loss of higher predators (e.g. birds, dolphins, sharks), and overall loss of biodiversity and estuary function. The WQIP uses abundance of microalgae (chlorophyll-a), water clarity (turbidity, Secchi depth) and the extent of seagrass as its primary indicators of estuary condition. Estuary Ecological Condition Targets (utilising trigger values) have been set for each of these indicators (Appendix 10).

Total nitrogen in the Myall Lakes is present in very high concentrations in the water column and appears to be relatively stable. This nitrogen is, however, mainly in the form of tannins and is not available to stimulate algal growth. In contrast to other nearby coastal lake systems, it is considered that chlorophyll-a concentrations in the Myall Lakes are related to total phosphorus rather than total nitrogen.

Our conceptual understanding is that ecosystems of this type are threatened by increased turbidity (decreased light penetration) and excessive nutrients (algal blooms, low phosphorus tolerance by charophytes). This leads to the belief by DECC Waters and Catchment Science that the indicators used in other coastal lakes (turbidity and chlorophyll) will still be suitable for the Myall Lakes system because they monitor the presence / consequence of the two primary threats: reduced light and nutrients.

DECC Waters and Catchment Science undertook sampling of water quality in the Myall Lakes in 2006/07. This data was used, along with DNR data (1999 to 2002) and NPWS / DNR Data (2003 to 2005) to map average chlorophyll-a concentrations for each part of the lake (Figure 2.13.2).

Figure 2.13.2 shows that concentrations of chlorophyll-a are highest in the river estuary sections of the Upper Myall and in the Bombah Broadwater, which has a higher degree of human disturbance than other areas of the lakes. This indicates that the Bombah Broadwater requires improvement (DECC Waters and Catchment Science 2006/07 data: turbidity about 5; all sampling data: chlorophyll-a 3.5). Myall Lake and Boolambayte Lake have relatively lower levels of chlorophyll-a than these areas. The current chlorophyll and clarity status for Myall Lake and Boolambayte Lake is very good (DECC Waters and Catchment Science 2006/07 data: chlorophyll-a 1.2 µg/L; turbidity 0.4 NTU; all sampling data: chlorophyll 2.9 [Myall Lake] and 2.5 [Boolambayte Lake]).

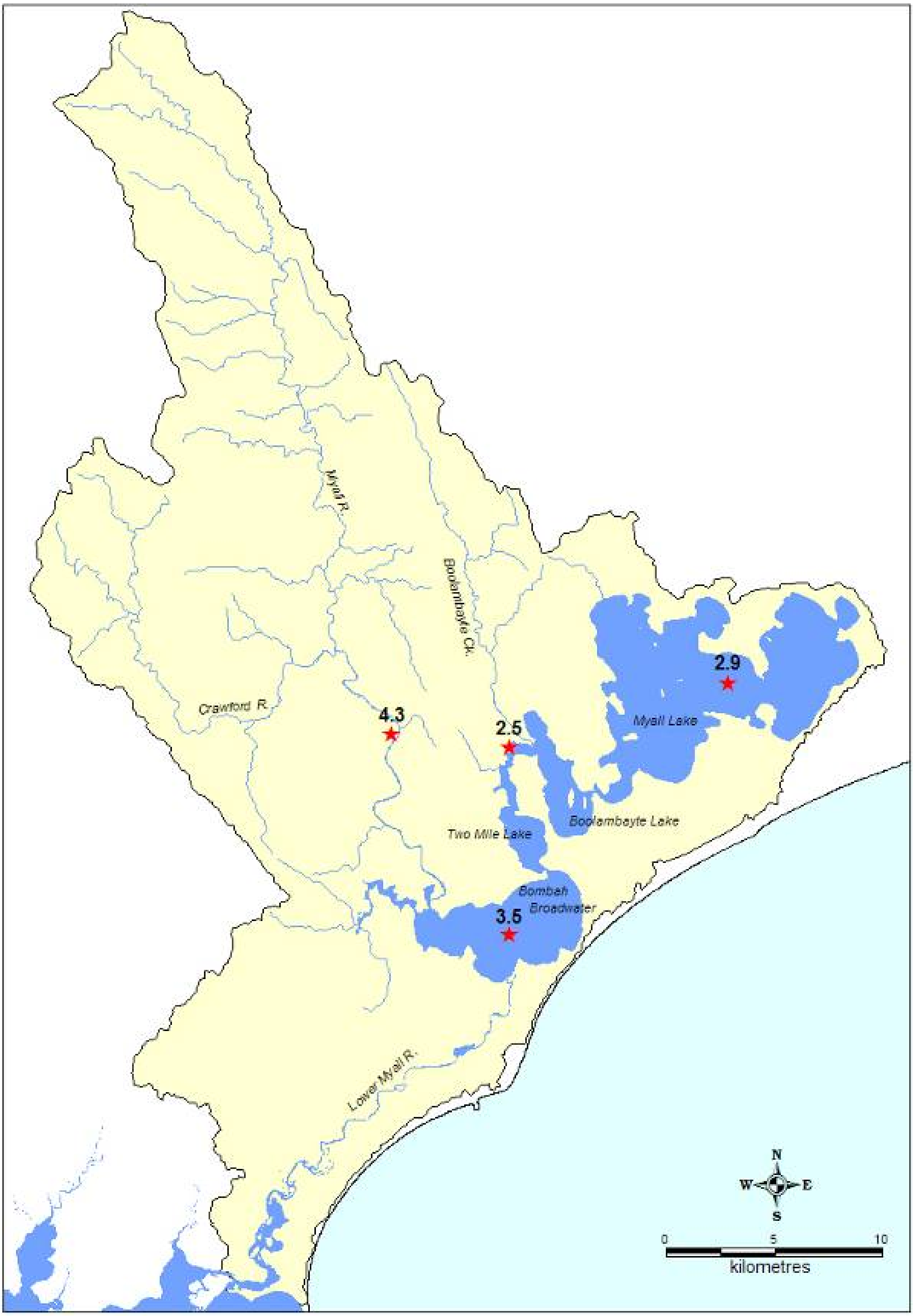


Figure 2.13.2. Mean chlorophyll-a concentrations (μg/L) calculated from DNR data (1999 to 2002), NPWS / DNR Data (2003 to 2005) and DECC Waters and Catchment Science data (2006/07).

2.13.2.6 Ecology in Myall Lakes

The Myall Lakes is a Ramsar site and their ecological values have been identified through the Myall Lakes Ecological Character Description (DECC 2008). As described in the Ecological Character Description, the ecology of the Myall Lakes is complex and poorly understood. The limits of our understanding consist of observations and inferences from correlated patterns of distribution. The physio-chemical water characteristics, and the distributions of macrophytes and algae, have been described in some detail (Dasey *et al*. 2004).

Before European settlement, macrophytes in Myall Lake and Boolambayte Lake would have been be similar, with seasonally fluctuating dominance between charophytes and *Najas*; Two Mile Lake and Bombah Broadwater would have had fewer *Najas*, and would have tended to be dominated by charophytes and seagrasses such as *Ruppia* and possibly *Zostera*. Dasey *et al*. (2004) and DECC (2007) are both of the opinion that the lakes would have all been mostly clear-water, low-nutrient, low-chlorophyll systems dominated by benthic macrophytes. The types of macrophytes would differ among lakes due to exposure to salinity.

Myall Lake and Boolambayte Lake are very different from most coastal lakes in NSW because they have substantial meadows of freshwater macrophytes, including large abundances of charophyte algae. Although total nitrogen is high in Myall Lake, it is in a dissolved organic form that does not block light. Experimental evidence shows that water clarity is related to total phosphorus in Myall Lake.

In Myall Lake, the distribution and abundance of charophytes and *Najas marina* is strongly dependent upon the soft organic bottom substrate known as gyttja.

The gyttja found in Myall Lakes appears to be unique in Australia (Dasey *et al*. 2005). It is believed to be very important in structuring and maintaining the characteristic submerged aquatic vegetation of the Myall Lakes (Dasey *et al*. 2004). Gyttja is a distinctive type of green-brown organic-rich sediment that is ubiquitous throughout the Myall, Boolambayte and, to a lesser extent, Two Mile lakes, but is not found in the Bombah Broadwater. In the Myall and Two Mile lakes, gyttja is up to 70 cm thick in places and forms an integral part of the aquatic ecosystem of the Myall Lakes. It consists of decomposed charophytes and macrophytes (*Najas*), and algal (primarily cyanobacterial) colonies. The relative contributions of charophytes and macrophytes (*Najas*) is still being debated, but it is clear that continued existence of the gyttja depends on seasonal decay of large macrophyte and charophyte biomasses. In shallow water sections and during summer blooms, benthic cyanobacteria are abundant in the gyttja, but in deeper waters there is a greater proportion of charophytes (M Dasey, pers. comm.). Studies have indicated that the gyttja layer commenced being deposited between 580 and 1,180 years ago (Drew *et al*.

2008[DG85]), showing that the transition to gyttja sediments in Myall Lake commenced centuries before European influence on the area.

The toxic blue-green algal blooms that dominated the lower Myall Lakes system in 1999 and 2000 did not impact the lakes where gyttja is abundant. The gyttja layer is extremely soft and anoxic, and appears to inhibit the colonisation of the lake floor by rooted macrophytes (e.g. *Vallisenaria*, *Potamogeton*) (Dasey *et al*. 2004). Charophytes (*Chara fibrosa* and *Nitella hyalina*) and *Najas marina* are, however, able to support themselves on top of the gyttja. Gyttja thus has a fundamental role in determining the distribution of macrophytes in the upper lakes.

Modelling has shown that the threats to Myall Lakes (in order of decreasing importance) are: Myall Lake perimeter catchment, Boolambayte Creek catchment and Myall River catchment. Bombah Broadwater is primarily affected by the Myall River and its catchment. Two Mile Lake is strongly influenced by Bombah Broadwater and Boolambayte Creek. Boolambayte Lake is influenced by Boolambayte Creek, Two Mile Lake and Myall Lake. Management actions for each part of the lake should concentrate on minimising threats in the priority catchments for that lake.

Myall Lake, Boolambayte Lake and Two Mile Lake are different from Smiths Lake and the main body of Wallis Lake in that they are essentially freshwater systems. Bombah Broadwater has characteristics that are similar to other coastal lake (e.g. more saline), although still appear to have more in common with the other Myall systems than Smiths and Wallis lakes. It is affected by the major sub-catchment of the Upper Myall and Crawford rivers, as well as by the Lower Myall River through tidal influences. Total phosphorus is considered to be the major driver of algal blooms in all parts of the Myall Lakes.

2.13.3. Ecological condition

The *National Water Quality Management Strategy, Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000) is the basis for the majority of decisions about water quality management in NSW. ANZECC provides for three ‘levels of protection’ for aquatic ecosystems:

1. *High conservation value:* systems that have a high ecological and / or conservation values, and are systems that are largely unmodified or have undergone little change. They are often found within national parks, conservation reserves or inaccessible locations.
2. *Slightly to moderately disturbed:* systems that have undergone some changes but are not considered so degraded as to be highly disturbed. Aquatic biological diversity

may have been affected to some degree but the natural communities are still largely intact and functioning.

3. *Highly disturbed:* systems that have undergone considerable degradation. Natural communities are largely not functional and nuisance species such as algae may be present in large volumes.

DECC has defined the typical features of lakes and coastal river estuaries in *High conservation value* to *Heavily impacted* condition, and identified where the different zones of the Myall Lakes fit in this scale (Appendix 10, Figures 2.13.3 and 2.13.4). Indicators of good ecosystem quality are high water clarity, low chlorophyll-a concentrations and very small amounts of green nuisance macroalgae.

This plan focuses on chlorophyll-a concentrations as the primary ecological indicator because the estuary models were able to provide a link between catchment nutrient loads (expressed as total nitrogen (TN) and total phosphorus (TP) inputs) and chlorophyll-a. [pt86]Nutrient dynamics in the Myall Lakes is not definitive and it is likely that algal growth is limited by both TP and TN. Water clarity and turbidity are still considered to be useful indicators. However, for the purposes of this Plan, it is assumed that actions which control nutrient exports from catchments will usually also control sediments, and thus contribute positively to protecting water clarity and seagrass extent targets.

This section of text summarises the current condition of the estuary zones, and relates them to the indicator levels for chlorophyll-a concentrations and turbidity defined by the Department of Environment and Climate Change (Appendix 10). Table 2.13.1 shows mean chlorophyll-a concentrations[13] and identify the order of change required to meet the indicator levels that would represent *High conservation value* and *Slightly to moderately disturbed* conditions. Note that these measurements were taken over a relatively short period of time. The order of change required to meet the indicator levels assumes that the conditions in the lake or river estuaries are adequately represented by the samples.

Myall Lake and Boolambayte Lake both have good ecosystem quality and can be considered to be of *High conservation value*. Indicators of good ecosystem quality would be high water clarity, low chlorophyll concentrations and very small amounts of green nuisance macroalgae. Two Mile Lake, while generally in good condition, has experienced higher levels of chlorophyll and nuisance algal growth, and appears to have lost some deepwater plant communities at the southern end (Dasey *et al*. 2004).

Bombah Broadwater in the Myall Lakes can be considered to be a *Slightly to moderately disturbed* ecosystem. The Bombah Broadwater has experienced some severe algal

13 Mean chlorophyll-a concentrations were calculated from DNR data (1999 to 2002), NPWS / DNR data (2003 to 2005) and DECC Waters and Catchment Science data (2006 to 2007).

blooms over the past decade and apparent loss of deepwater plant communities. The severe algal blooms were associated with large rainfall events that transported nutrients to the system via the Myall River catchment, and were large enough to drive the lake salinity to very low levels for an extended time (Dasey *et al*. 2004). Indicators of disturbed condition would be poor water clarity, moderate chlorophyll concentrations and obvious moderate to large amounts of green nuisance macroalgae.

The condition of the lakes compared to the target levels for different ecological conditions is shown in Figure 2.13.3 and Table 2.13.1. Note that the condition of the Lower Myall river estuary has not been monitored or modelled during the development of this Plan. Water quality and ecological condition are only reported on for Bombah Broadwater and all lakes and river estuaries upstream of this lake.

Table 2.13.1. Average chlorophyll-a concentrations (µg/L) recorded in the Myall Lakes by DECC Waters and Catchment Science in 2006/07, and their relationship to indicator levels representative of *High conservation value* and *Slightly to moderately disturbed* water bodies. See Figures 2.5.5 and 2.5.6 for more explanation of the meaning of these concentrations for ecological condition. Averages were calculated from DECC Waters and Catchment Science chlorophyll-a measurements (2006/07), DNR data (1999 to 2002) and NPWS / DNR data (2003 to 2005).

Waterbody	Measurements	High conservation value		Slightly to moderately disturbed	
		Level [a]	Decrease to achieve level (%)	Level [a]	Decrease to achieve level (%)
Myall Lake	2.9	3.2	0.0	--[DG87]	--
Boolambayte Lake	2.5	3.0	0.0	--	--
Bombah Broadwater	3.5	3.0	14.3	--	--
Upper Myall River (Middle Estuary)	4.3	4.2	2.4	5.0	0.0

a: Indicator levels reflect the amount of chlorophyll-a that could be expected in systems that are of *High conservation value* or are *Slightly to moderately disturbed*.

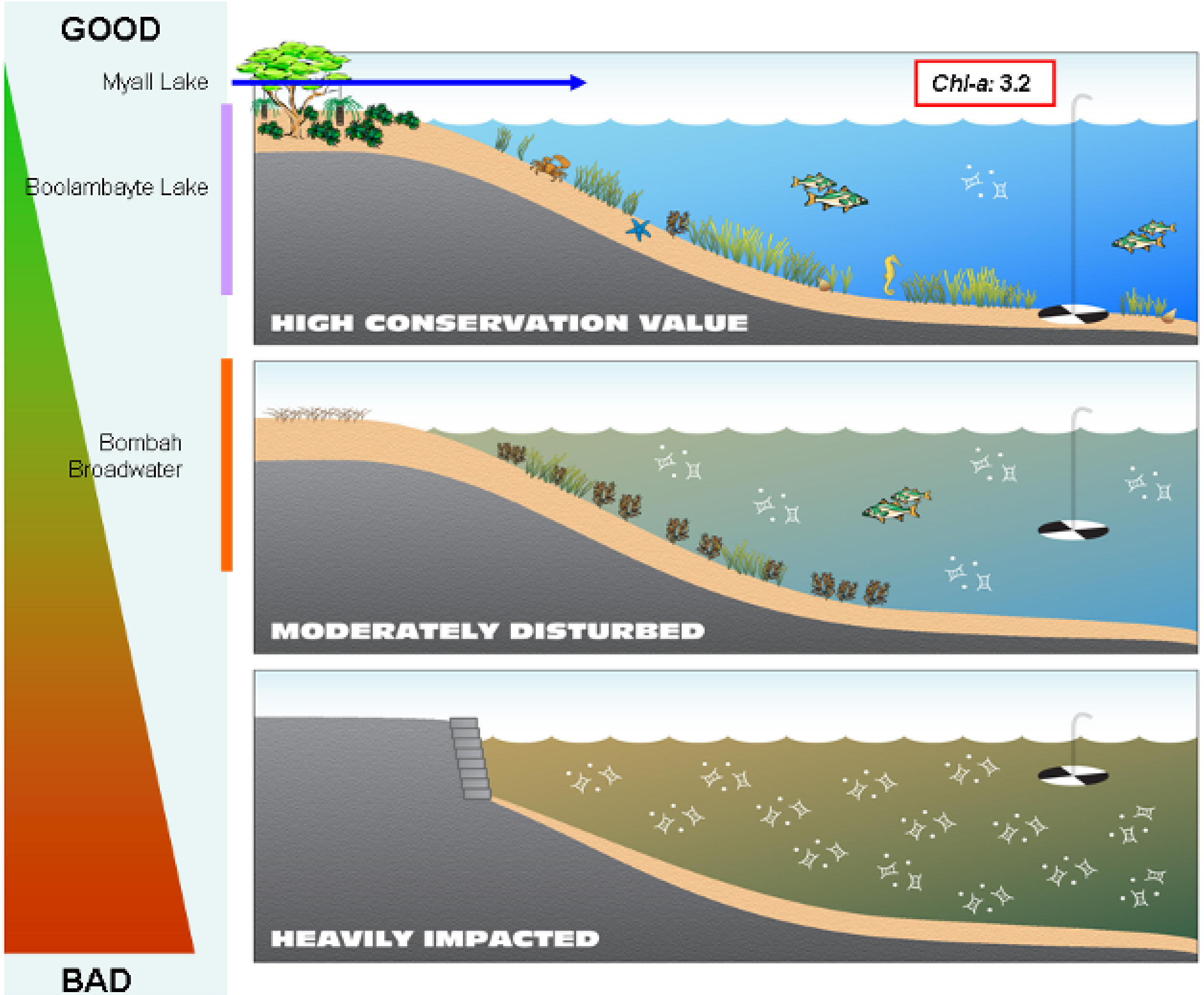


Figure 2.13.3. Current ecological condition of the Myall Lakes water bodies of Myall Lake, Boolambayte Lake and Bombah Broadwater. Indicative levels of chlorophyll-a concentrations (µg/L) are shown for these *High conservation value* and *Slightly to moderately disturbed* water bodies.

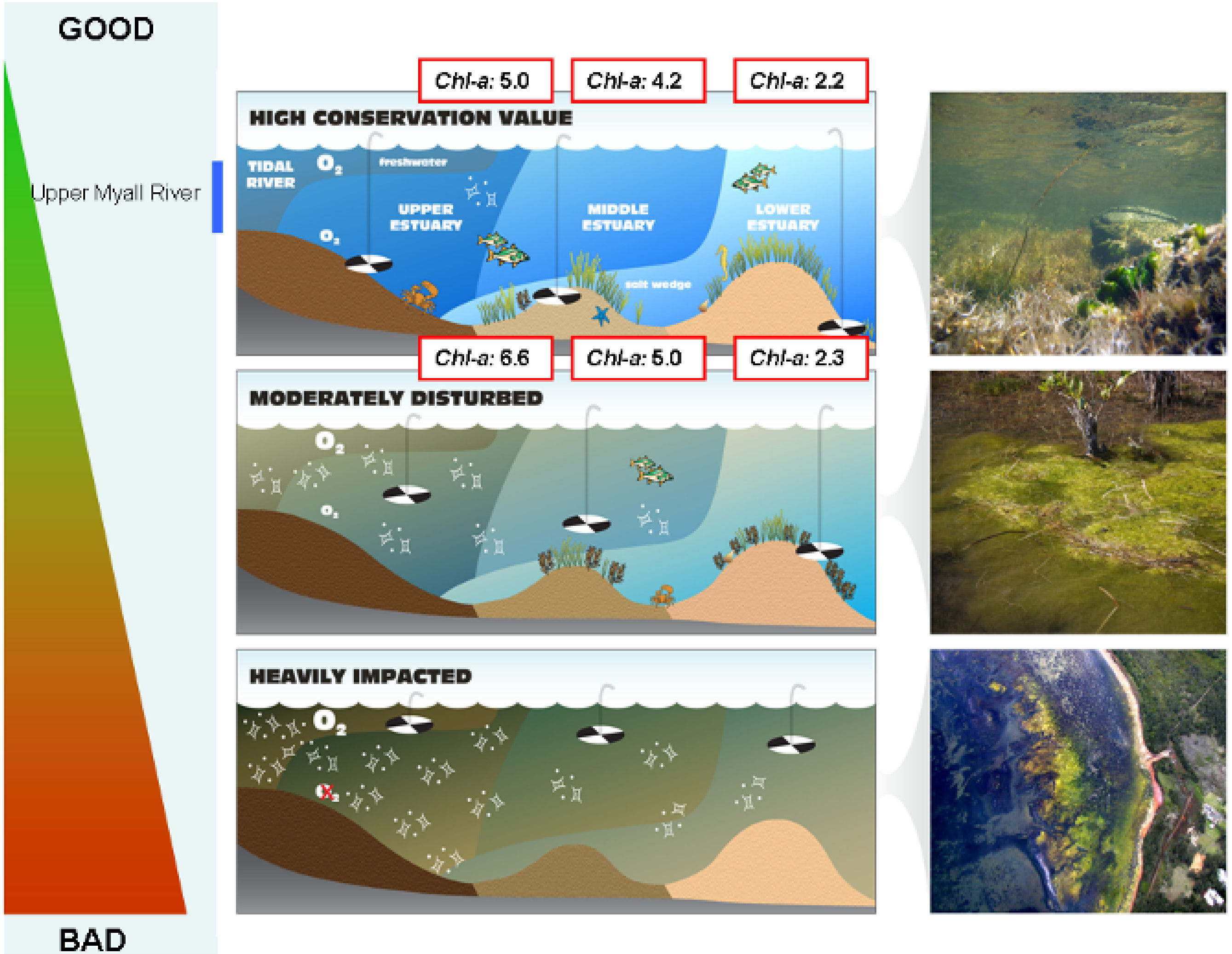


Figure 2.13.4. Current ecological condition of the Upper Myall River estuary. Shows its proximity to the levels of chlorophyll-a concentrations (µg/L) representative of *High conservation value* and *Slightly to moderately disturbed* water bodies. Chlorophyll-a concentrations are shown across three estuary zones: Upper, Middle and Lower Estuary.

2.13.4 Hydrodynamics

The Myall Lakes system is somewhat unique in that, unlike most other NSW coastal lake systems, the lakes are not subject to regular tidal exchange. The flow constrictions applied by the estuarine Lower Myall River ensure that only the southern portion of the Bombah Broadwater is subject to tidal exchange (DIPNR 2004[DG88]; NPWS 2002). Such limited tidal exchange results in long water retention times, assessed to be between 400 and 800 days, and great differences in the salinity characteristics of the four lakes (DIPNR 2004). The southern parts of Bombah Broadwater show distinct estuarine influences. Boolambayte and Myall Lakes are, in effect, freshwater systems occasionally exposed to saline water during extended periods of low catchment runoff (DIPNR 2004; NPWS 2002). Low flushing rates and long water residence times ensure that the lake system is essentially a sink for sediment and nutrient flows from the catchment, and therefore highly susceptible to human activity with the catchment (DIPNR 2004; NPWS 2002; Smith 2001).

2.13.5 Description of in-stream attenuation and remobilisation processes

There are few studies of in-stream nutrient attenuation and remobilisation processes in Australia. A description of in-stream nutrient attenuation and remobilisation processes, specific to the Great Lakes area, cannot be made without targeted experiments (e.g. nutrient uptake) and monitoring (e.g. discharge effects). This work was beyond the time and resources allocated for the CCI catchment and estuary modelling projects, although it has been recognised as a priority area for future research (see Appendix 7).

2.13.6. Catchment loads and pollutant generation

As part of the Coastal Catchments Initiative, models of nutrient and sediment transport have been developed for the Myall Lakes catchment area. These models allow the current loads of pollutants (annual average) for each of the sub-catchment areas that contribute to the lakes, as well as the projected loads under a range of land use and management scenarios, to be estimated. The sub-catchments for which catchment loads have been estimated using these models are shown in Figure 2.13.1. A description of the seasonality of loads and the implications of this for the Plan are given in Appendix 12.

The areas, and current loads of sediment and nutrients being generated in each of the sub-catchments, are given in Table 2.13.2. Definitions of land use types can be found in Section 2.12. The accuracy of modelled outcomes is presented in Appendix 5.

Table 2.13.2. Area and pollutant exports from the Myall Lakes sub-catchments (estimated using the DSS). The table shows absolute values as well as the percentage contribution of the sub-catchment to the catchment total.

Sub-catchment	Area		TSS		TN		TP	
	ha	%	tonnes	%	kg	%	kg	%
Myall Lake	7,771	10	740	11	4,546	10	545	10
Boolambayte Creek	11,131	14	451	7	5,140	11	300	6
Upper Myall River	23,956	31	3,385	52	20,947	45	1,548	29
Crawford River	11,926	15	271	4	6,394	14	991	18
Bombah Broadwater	12,095	15	617	9	5,467	12	870	16
Lower Myall River *	11,615	15	1,040	16	3,667	8	1,106	21
Total	78,494		6,504		46,161		5,360	

* Condition in the Lower Myall River estuary is not reported on in this Plan as catchment runoff into the Lower Myall River has a minor influence on the Bombah Broadwater – there is a average net outflow of water from the Bombah Broadwater and limited tidal influence, and therefore limited exchange between the Lower Myall River.

This table shows that while the Upper Myall River is the largest of the sub-catchments displayed, it contributes proportionally more TSS and TN than would be expected, given its size. Other sub-catchments are of a similar size to each other, with the Myall Lakes sub-catchment being the smallest. The Myall Lakes sub-catchment produces nutrients and sediments that are proportional to its area. Boolambayte Creek produces less sediments and nutrients than would be expected based on its area. Both the Bombah Broadwater and the Crawford River sub-catchments produce less TSS and TN, but slightly more TP, than would be expected based on area. The Lower Myall River sub-catchment produces expected levels of TSS, but lower levels of TN and higher levels of TP, than would be expected based on area.

A discussion of the contribution of different land use activities to the loads in each sub-catchment is given in Appendix 19. Figure 2.13.5 provides a summary of the contribution made by land use to the catchment area, as well as to the TSS, TN and TP load across the entire catchment. The land use classes that are targeted in the modelling presented in Section 2.15 are agricultural lands. These comprise 22% of the land but contribute 52% of the TN, 56% of the TP and 83% of the TSS. The modelled actions in this Plan do not address the management of forestry, protected vegetation or native vegetation.

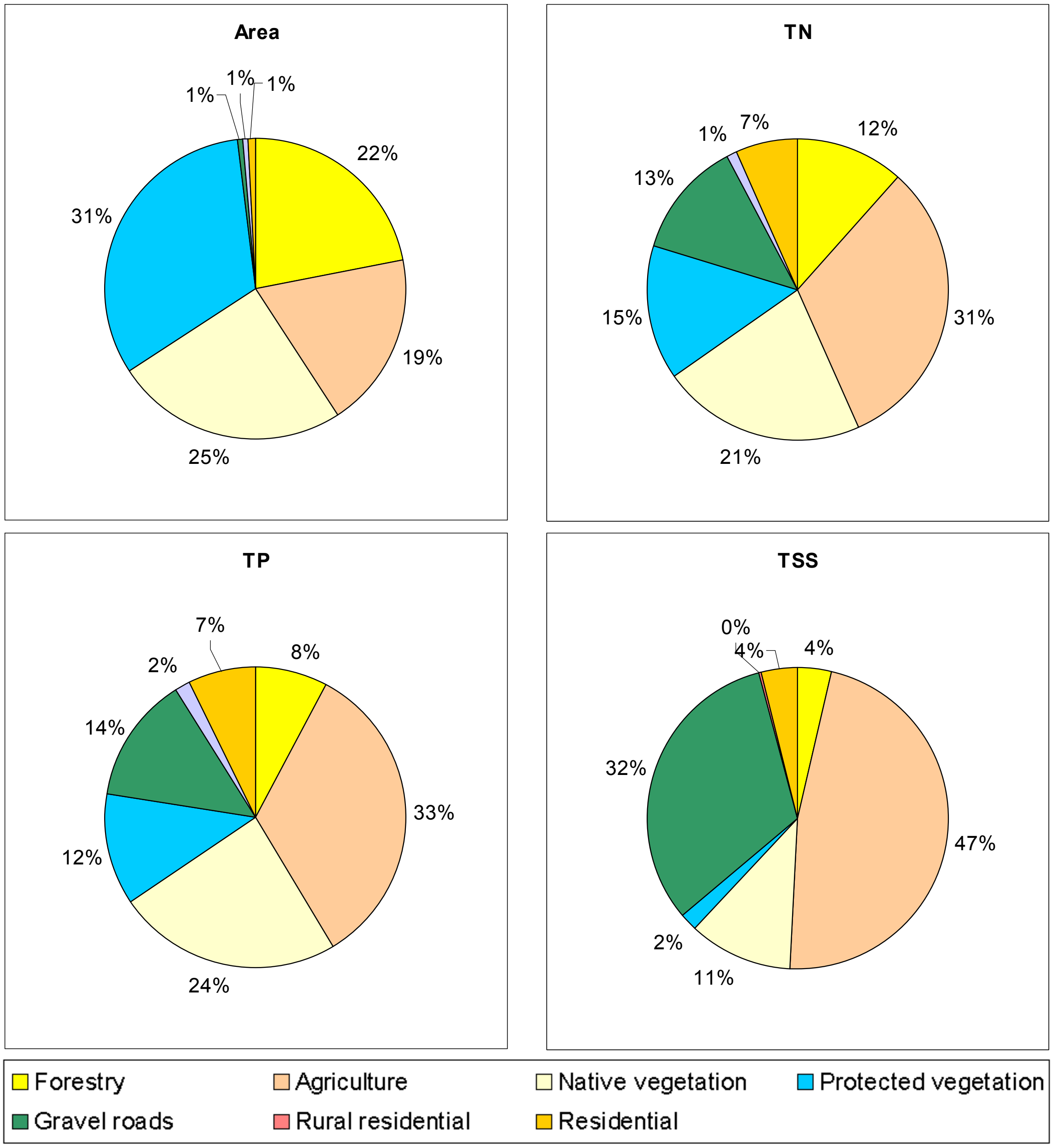


Figure 2.13.5. Relative contributions of land use activities to pollutants (TN, TP) and sediments (TSS) in the Myall Lakes catchment. For a description of land use categories shown in the figure please see Section 2.1.

This figure shows that while protected vegetation accounts for a substantial area across the Myall Lakes catchment, it contributes relatively little sediments or nutrients. The largest contributors of sediments are agricultural areas and unpaved roads. Gravel roads produce particularly high quantities of sediments compared to the relatively small area contribution they make to the catchment. Their contributions to nutrient runoff are less than for sediments, but are still substantially elevated above what could be expected based on their area. Agriculture also produces a substantial proportion of nutrients, more than could be expected based on area alone. Residential areas account for a very small proportion of the catchment but are also relatively large producers of nutrients and, to a lesser extent, sediments.

2.13.7 Summary

This section describes the current condition of the Myall Lakes system, including the condition of the lakes as well as current catchment loads. It also summarises the Ecological Condition Targets that have been defined as part of the WQIP process for Myall Lakes. This has highlighted both the current good condition of much of the Myall Lakes system as well as the threats facing this system. Overall, the following statements can be made about the Myall Lakes system:

- The Myall Lakes system has very limited connectivity with the ocean and behaves as a freshwater lake for much of its area. This means that the system is very sensitive to any increases in pollutant loads.
- Myall Lake is currently in a *High conservation value* condition. This reflects its relatively undeveloped catchment area. While there is some connection between Bombah Broadwater, Boolambayte Lake and Myall Lake, this lake is predominantly affected by its own catchment area and not those of the lower lakes.
- Boolambayte Lake (including Two Mile Lake) is also in a *High conservation value* condition although it is also subject to pressures from Bombah Broadwater, which has considerably worse water quality. This lake is impacted by its own catchment, area as well as by Bombah Broadwater and Myall Lake.
- Bombah Broadwater is currently in a modified condition. The numbers in Table 2.13.2 alone do not illustrate the excessive damaging pollutant loads affecting the condition of the lake. Bombah Broadwater is the receiving waters for the Upper Myall River, Crawford River, Bombah Broadwater and Lower Myall River (tidal) sub-catchments, which comprise 76% of the total catchment area and contribute 81%, 79% and 84% of the TSS, TN and TP, respectively. These catchment loads, coupled with long water retention times and low flushing, help to explain the decline in the health of Bombah Broadwater and its susceptibility to algal blooms.
- A large part of the catchment of the lakes, particularly of Myall Lake, is protected in national parks. This provides a substantial buffer against deteriorating water quality and is likely to be part of the reason for the high quality of water in the upper lakes.
- The whole Myall Lakes system is under pressure from elevated pollutant loads from agricultural lands, especially in the Upper Myall River and Crawford River sub-catchments, and from runoff from unpaved roads. Current urban areas are a small contributor to catchment loads given their small area, but water quality is under risk if development pressures are not managed well into the future. Given the much higher loads per unit area contributed by urban areas than by other land uses, increases in urban area that do not have effective management controls built in are likely to lead

to substantial deterioration of the lakes system, and may push Myall Lake and Boolambayte Lake towards a modified condition.

2.14 Myall Lakes – Setting targets for water quality management

2.14.1 Using community values to help set targets

In accordance with the *National Water Quality Management Strategy, Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000) the following process shown in Figure 2.14.1 was utilised to develop water quality targets for Wallis, Smiths and Myall lakes.

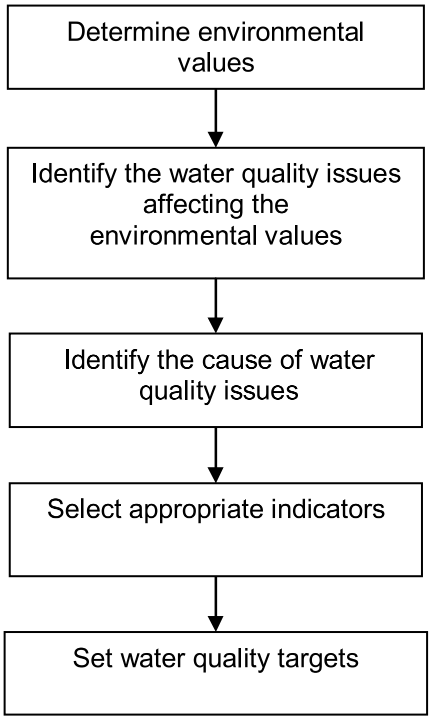


Figure 2.14.1. Process for developing water quality targets for Wallis, Smiths and Myall lakes (Source: Adapted from ANZECC & ARMCANZ 2000).

The first step in the process of identifying the environmental values, water quality issues and water quality targets for the local waterways involved checking that the existing values that had been set for the lakes by the NSW government in 1997 were still relevant. These environmental values were agreed by the community and endorsed by the NSW government.

Information on the existing environmental values for the Myall Lakes (that were then subdivided into sub-catchment areas), and the intended process of reviewing these values with the Advisory Committee and community, can be found in Environmental Values Background Report (GLC internal unpublished document).

A workshop was held with the Advisory Committee to review the existing environmental values, and to make changes or additions. The results of this workshop are summarised in Report on Environmental Value Setting by AC (GLC internal unpublished document).

After trialling a similar workshop (to that held with the Advisory Committee) with the Wallis Lake Estuary Management Committee, it was decided to use a simpler and more accessible method for reviewing the environmental values with the community. Thus, a ‘Recall Emotion Meaning Action’ method was utilised in community workshops to ascertain how community groups value and use their waterways. This method and the process used at workshops, as well as the steps taken to involve industry groups and the community in reviewing the environmental values. is described in the Engagement Strategy and summarised in the Engagement Report (Appendix 1).

The activities, uses and important aspects of the waterways suggested by the participants were combined with the values set by the Advisory Committee. The resulting environmental values for Myall Lakes are presented in Table 2.14.1.

Table 2.14.1. Environmental values and uses given by stakeholders and community for Myall Lakes.

Aquatic ecosystems	Industry – Consump-tion	Primary recreation	Secondary recreation	Visual apprec.	Cultural	Group
✓	✓	✓	✓	✓		Existing Environmental Values (EPA 1999)
✓	✓	✓	✓	✓	✓	Advisory Committee
✓		✓	✓	✓		Getaway Luxury Houseboats
✓	✓	✓	✓	✓	✓	HN / TG progress Association / Myall koala group
				✓		Great Lakes Coastal Land mgrs network
✓	✓	✓	✓	✓	✓	Hunter-Central Rivers Aboriginal Cultural & Environmental Network (ACEN) – CMA Partnership Committee
✓	✓	✓	✓	✓	✓	Pindimar / Bundabar Community Association & residents
		✓	✓	✓		Karuah / Great Lakes Landcare, Nabiac Landcare and Dyers Crossing Landcare
		✓	✓	✓		Forster U3A
✓	✓	✓	✓	✓	✓	**Summary of current values**

As shown in Table 2.14.1, aquatic ecosystems were valued by the community for Myall Lakes. The *Framework for marine and estuarine water quality protection: A reference document* states that “where more than one environmental value applies to the same receiving waters, the environmental values need to be prioritised and the most stringent guideline should be used (ANZECC & ARMCANZ 2000). The most stringent guideline will in many cases also protect the other environmental values. In most cases, the water quality requirements for protection of *aquatic ecosystems* are the most stringent of all the environmental values." (Department of Environment and Heritage 2002, p. 13).

For this reason, water quality targets were developed to protect aquatic ecosystems and, by default, to protect the other values. The ANZECC Guidelines suggest that locally relevant environmental indicators are more useful than 'single number' guidelines that are applied universally. To derive locally relevant indicators to measure the health of aquatic ecosystems, scientific assessments of the local biological community were undertaken. These assessments ascertained whether biological integrity is being maintained and determined local trigger values for the maintenance of this integrity. The locally relevant indicators that were determined were chlorophyll-a concentration, charophyte abundance and water clarity.

The local trigger values established were based on the Aquatic Ecosystem 'levels of protection'. Aquatic ecosystems can be protected to three different levels, depending on the current ecological condition of the ecosystems:

1. High conservation value
2. Slightly to moderately disturbed
3. Heavily disturbed.

Figures 2.13.3 and 2.13.4 show the current ecological condition of the Myall Lake, Boolambayte Lake, Bombah Broadwater and Upper Myall River estuary relative to these categories. Details on these trigger values and how they were determined are outlined in Appendix 10.

Results from scientific research were used to determine the 'current' condition for each lake and potential target values for each indicator. Based on this research and the expectations of the community, the Advisory Committee selected an appropriate level of protection to aspire to and established *draft* Ecological Condition Targets for the indicators.

Possible management scenarios were tested with the DSS to ensure that targets were realistic and technically feasible. The agreed targets are documented in Section 2.14.2.

As previously mentioned, protecting aquatic ecosystems also protects many of the other values the community identified for Wallis, Smiths and Myall lakes. For example, water clarity is important for charophyte growth, and also to protect the recreational benefits of visual appreciation, primary and secondary recreation, and to protect cultural values associated with natural areas.

2.14.2 Ecological Condition Targets and catchment loads

Separate Ecological Condition Targets, and feasible chlorophyll-a and catchment load reductions, have been identified for the three lakes included in the Myall Lakes system (Myall Lake, Boolambayte Lake and Bombah Broadwater). Sections 2.14.2.1 to 2.14.2.4 describe the community values and aspirations for setting Ecological Condition Targets for each of the Myall Lakes water bodies. Section 2.14.2.5 describes how Ecological Condition Targets were derived based on the percentage change in chlorophyll-a concentrations to reach an ecological condition of *High conservation value.* This section then considers these targets in comparison to the feasible percentage reductions in chlorophyll-a concentrations modelled with implementation of the actions in this Plan. Section 2.14.2.6 presents feasible catchment load reductions from the Myall Lakes sub-catchments that together could meet the feasible reductions in chlorophyll-a concentrations over the seven years of the Plan.

Feasible reductions presented in Table 2.14.2 reflect the reduction in chlorophyll-a concentrations modelled in the DSS with implementation of the remediation actions described in Section 2.15.1. Underlying this modelled information is an expert judgement on the degree and timing of uptake of different measures, the resources required for each program, and the effectiveness of actions (see Appendix 20 for details). These predictions provide an estimate of the change that will be experienced in seven years should the Plan be implemented in its entirety.

The results in this section demonstrate the importance of protecting the lake against further deterioration. Remediation is very costly, time-consuming and is often limited in what can be achieved. Protection of areas of existing high value, such as Myall Lake, is very important because the costs and limitations of remediation are such that any damage to these areas is likely to be irreversible. Likewise, further deterioration of modified areas of the lake is unacceptable to the community and is likely to be very difficult to reverse. The listing of the Myall Lakes system as a Ramsar Wetland of International Importance carries an obligation for Australia as a signatory to the Ramsar Convention to manage Ramsar sites to protect ‘ecological character’. Any actions that result in the deterioration of those characteristics should be seen as contravening the terms of the agreement (Appendix 18; NPWS 2002).

Population pressures and land use changes in the Myall Lakes catchment mean that some level of protection and remediation is required simply to maintain the current level of water quality without any expectation of improvement, even in areas that are currently damaged. As discussed in Section 2.13.4, the low flushing rates and long water residence times in the Myall Lakes system ensure that it is essentially a sink for sediment and nutrient flows from the catchment, and therefore highly susceptible to human activity with the catchment (DIPNR 2004; NPWS 2002; Smith 2001).

There is a degree of natural variability in relation to catchment loads and estuary concentrations of pollutants. These targets relate to the average annual load or mean concentration calculated over a long period. The way in which the targets have been formulated takes into account some of the natural variation expected in these environments (Appendix 10).

Not all the Ecological Condition Targets proposed in this section are feasible at present, given current technology and funds available. However, they do provide an aspirational goal towards which we are moving using the actions proposed in the Plan. The targets are intended as triggers for action and, in this context, if they are exceeded occasionally it is not of significant concern. However, if there is a sustained trend of exceedence then there would be a need to undertake further investigation and action. There may also be the potential to establish short-term ecological condition targets to be measured subsequent to rainfall events. This approach requires further investigation and consideration for future monitoring programs (Appendix 10).

2.14.2.1 Myall Lake Ecological Condition Target

The body of Myall Lake should be managed to maintain its current near-pristine condition. There is zero tolerance within the Advisory Committee and the community for deterioration in the condition of the lake particularly because it is a Ramsar site. From discussions when setting environmental values (Section 2.14.1), the community and the Advisory Committee indicated that they would prefer as much improvement in lake condition as is financially possible. This improvement was seen as necessary to provide a buffer against possible unforeseen threats and future sources of pollution that may not have been accounted for in the modelling.

Myall Lake Ecological Condition Target: No deterioration. Improvements to establish buffer.

The consequences of a single erosion gully close to the lake on conditions in the Coomba Bay area of the Wallis Lake catchment (Appendix 11) emphasises the scale of risks that can stem from localised catchment management issues. The southern end of Wallis Lake is in a similar condition to Myall Lake in that there is little exchange of water with the ocean and, consequently, the perimeter catchment strongly affects the water quality. In such situations, even seemingly minor failings in catchment management can have large, immediate and ongoing effects on the water quality and ecology of the lakes. The community and Advisory Committee expressed serious concern about the potential for events such as this to occur in the Myall Lake and indicated a strong preference for preventative actions to be undertaken to reduce the risk of such occurrences.

If conditions are allowed to deteriorate, in particular if there are increased loads of sediments and nutrients entering this lake, then symptoms of poor health (high chlorophyll levels, turbid water, poor light penetration, loss of bottom-dwelling plants) will begin to occur and a unique ecosystem will be lost.

2.14.2.2 Boolambayte Lake Ecological Condition Target

Similar to Myall Lake, Boolambayte Lake has Ramsar listing, is in a very good ecological condition and can be considered to be of *High conservation value* status. The community indicated that there is no tolerance for any deterioration in the quality of this lake and that they have a preference for actions to be undertaken to provide a buffer against possible future increases in pollutants, including from one-off events.

Boolambayte Lake Ecological Condition Target: No deterioration. Improvements to establish buffer.

2.14.2.3 Bombah Broadwater Ecological Condition Target

The Bombah Broadwater and its catchment should be managed to improve its current modified condition to achieve *High conservation value* condition. The community and Advisory Committee want the health of the Broadwater to improve and have no tolerance for deterioration in the condition of the lake, given that it is a Ramsar site and there are concerns about the incidence of blue-green algal blooms. To improve the health of the system, chlorophyll-a levels should be reduced. A long-term goal has been established to reduce chlorophyll-a levels back to *High conservation value* levels (i.e. 14% reduction).

Bombah Broadwater Ecological Condition Target: 14% reduction in chlorophyll-a concentration levels.

Estimates of feasible changes were created for seven years based on an assessment of the physical and financial feasibility of changes in management practices. Feasible changes were estimated and have been set at a 2.4% reduction in chlorophyll-a.

2.14.2.4 Upper Myall River Ecological Condition Target

The Upper Myall River and its catchment should be managed to improve it from its current slightly modified condition to achieve a *High conservation value* condition. This means chlorophyll-a levels should be reduced. A long-term goal has been established to reduce chlorophyll-a levels back to *High conservation value* levels (i.e. 2.4% reduction).

Upper Myall River Ecological Condition Target: 2.4% reduction in chlorophyll-a concentration levels.

Changes that move Bombah Broadwater back to *High conservation value* status will do the same for the Upper Myall River.

2.14.2.5 Feasible reductions in chlorophyll-a concentrations

Ecological Condition Targets for the Myall Lakes and Upper Myall River estuary are summarised in Table 2.14.2.[14] These targets are based on assumptions derived from discussions with community members and Council, as well as modelling and analysis. Ecological Condition Targets were defined for each estuary zone by comparing monitoring data to chlorophyll-a concentrations indicative of *High conservation value*. Targets represent the percentage change required in chlorophyll-a concentrations to reach *High conservation value* (see Section 2.13.3). The monitoring data used to calculate the Ecological Condition Targets is assumed to adequately represent the average condition of the Myall Lakes and Upper Myall River estuary.

Feasible reductions presented in Table 2.14.2 reflect the modelled reduction in chlorophyll-a concentrations achieved by implementing the modelled remediation actions described in Section 2.15.1. Underlying this information is an expert judgement on the degree and timing of uptake of different measures, the resources required for each program, and the effectiveness of actions. The Plan has been developed to guide water quality improvement actions for the next seven years. The Plan and associated modelling will be reviewed after six years and, allowing adequate time for this to occur, a revised Plan will be developed by year 7.

14 Condition in the Lower Myall River estuary was not modelled during the CCI or for this Plan. Ecological condition targets are not defined for this part of the Myall River.

Table 2.14.2. Ecological Condition Targets and predicted reduction in chlorophyll-a concentrations with implementation of the WQIP in the Myall Lakes.

	Ecological Condition Target	Feasible reduction in chlorophyll-a concentration (%) [15]
Myall Lake	No deterioration, improvements to establish buffer	1.6
Boolambayte Lake	No deterioration, improvements to establish buffer	1.9
Bombah Broadwater	14% reduction in chlorophyll-a concentration	2.4
Upper Myall River	2.4% reduction in chlorophyll-a concentration	--[DG89] [a]

a: The Upper Myall River was not modelled in this Plan due to the way in which rivers were represented in the hydrodynamic model (see Section 1.5.2 and Appendix 5). Changes that achieve the target for Bombah Broadwater should also achieve the target for the Upper Myall River estuary.

2.14.2.6 Catchment loads

These Ecological Condition Targets imply reductions in catchment loads for the Myall Lakes. Decision Support Systems, such as that used to develop this Plan, have been demonstrated to be accurate in terms of the direction and magnitude of impacts, but are not assured as predictive models in the sense of accurately predicting precise future catchment export loads or resultant estuarine concentrations. In order to limit the effect of any such inaccuracies and produce the most accurate predictions of potential changes in loads and concentrations under the Plan, the magnitude and direction of change from the modelling has been used in conjunction with measured data (rather than modelled data) wherever possible to predict concentrations.

Feasible catchment load reductions for the Myall Lakes are as given in Table 2.14.3. These predicted load reductions correspond to the feasible reductions in chlorophyll-a concentrations presented in Table 2.14.2. The modelled actions are discussed in Section 2.15.1.

Variation in feasible catchment load percentage reductions across sub-catchments is discussed in Section 2.15.1.2.

15 Rural Actions were designed as 7-year programs. Costs for maintaining these levels of change past year 7 were estimated but no option for ramping up programs after year 7 was considered. Urban options were typically run out over 30 years because they depend redevelopment rates, etc. In Myall Lakes, the majority of actions considered related to rural management practice change. This means that the estimate of feasibility after 30 years underestimates what could be achieved if rural programs are ramped up after year 7. It is recommended that programs be revised and new estimates of cost and impact be developed as part of the 7-year review of the Plan to ensure that estimates of feasible change reflect new understanding and technology, and remove this limitation.

Table 2.14.3. Predicted catchment load reductions for the Myall Lakes system following implementation of the WQIP. [16]

	TN		TP		TSS	
	Current load (kg)	**% load reduction**	**Current load (kg)**	**% load reduction**	**Current load (tonnes)**	**% load reduction**
Myall Lake	4,603	-2.2	551	-2.0	754.2	-1.9
Boolambayte Creek	5,186	-1.7	304	-1.8	462.1	-1.6
Upper Myall River	28,337	-6.1	2,226	-6.6	6,005	-3.7
Crawford River	6,496	-4.2	1,004	-7.3	298	-4.5
Bombah Broadwater	8,126	-3.3	1,381	-2.8	1,862	-0.7
Lower Myall River [a]	4,400	-2.4	3,485	-1.2	1,886	-2.8

a: Condition in the Lower Myall River estuary is not reported on in this Plan, as catchment runoff into the Lower Myall River has a minor influence on the Bombah Broadwater. There is an average net outflow of water from the Bombah Broadwater and limited tidal influence, therefore limited exchange between the Lower Myall River.
[DG90]

2.15 Myall Lakes – Management strategies to achieve Ecological Condition Targets

The DSS developed as part of the Great Lakes CCI was used to conduct an exploratory analysis on the impact of potential rural and urban actions on nutrient and sediment exports into the Myall Lakes and, as a consequence, changes in estuary condition. These changes were related to Ecological Condition Targets that were defined for each estuary zone in Section 2.14.

Section 2.15.1 describes the results from the exploratory analysis of potential management actions for the whole catchment area of Myall Lakes. Analysis of costs and feasibility of actions was then undertaken to further refine the strategies recommended in the Plan. These recommended strategies are summarised in Section 2.15.2. A benefit-cost analysis of the Myall Lakes Plan is summarised in Section 2.15.3 and detailed in Appendix 15. Additional exploratory analysis was undertaken for the Crawford River drinking water supply catchment and is detailed in Appendix 21. The actions investigated in the Crawford River analysis have not been presented as part of this Plan, as they have not been feasibility tested; further engagement with key stakeholders is required prior to adoption.

16 Catchment load targets equivalent to the long-term Ecological Condition Target cannot be calculated without further assumptions on prioritisation and feasibility of actions in sub-catchments that go beyond the strategies described in this Plan. This is because there are many possible ways of achieving Ecological Condition Targets through changes in sub-catchment loads.

2.15.1. Exploratory analysis of potential remediation and protection actions

The Myall Lakes management strategies contain actions targeted to two specific purposes:

- to *remediate* existing areas of high pollutant loads, and thus provide reductions in catchment loads and estuary concentrations
- to *protect* areas of high conservation status that are currently providing substantial water quality benefits to the rivers and lake systems.

Protection actions are assumed in the Plan to not improve water quality but rather protect against further decline in water quality. The old adage – that it is cheaper to protect what is left than to replace it once it is gone – has been demonstrated to be true in this project and further emphasises the importance of protection actions as a key component of the Plan. Given the costs of remediation actions and the limits to their effectiveness at improving water quality at the catchment scale, it is essential that a range of protection actions – including protecting existing buffers and vegetation, and placing limits on inappropriate developments – are undertaken to ensure that water quality does not deteriorate further in the lakes. Damage to Coomba Bay from a single dam failure in Wallis Lake illustrates the magnitude of possible events caused by a lack of protection. However, it is often difficult to fully value the benefits of protection, as it can be difficult to estimate the damage that would be done without these actions taking place. By contrast, the effects (and benefits) of remediation actions are much easier to estimate.

Section 2.15.1.1 introduces the proposed remediation and protection actions for the Myall Lakes. The DSS modelled the proposed remediation actions, and their impact on catchment exports and estuary condition, over a seven-year period. Many of the actions identified in the Plan are designed to be implemented over more than seven years (e.g. Wetland protection and Water Sensitive Development of Greenfield sites). In these cases, the impact at seven years assumes that implementation of these actions is in progress, rather than completed. For the purposes of the benefit-cost analysis (Appendix 15), the costs and benefits of these programs were estimated over a 30-year period. Details on the programs and associated costs are outlined in Appendix 20.

Sections 2.15.1.2 and 2.15.1.3 examine the modelled impact of remediation actions on catchment exports and subsequent estuary condition. Although the effect of individual protection actions could not be modelled in the DSS, an estimate of the impact of *not* implementing *all* protection actions recommended in this Plan is provided in Figures 2.15.1 and 2.15.2. This section discusses the results of two alternative futures – full implementation of the WQIP remediation and protection actions, or no implementation of protection actions and only the existing remediation actions from current programs.

Section 2.15.1.4 discusses the cumulative costs and cost-effectiveness of the modelled remediation actions.

2.15.1.1. Description of remediation and protection actions

Remediation actions modelled using the DSS for rural areas of the Myall Lakes catchment are shown in Table 2.15.1. Remediation actions can be:

- *existing programs*: works currently being implemented across the catchment (e.g. sustainable grazing programs focussed on achieving groundcover management actions). This Plan models existing programs as fully implemented in both the 'No Plan' and 'WQIP' alternative futures. However, at the time of writing this Plan, the existing programs for the Myall Lakes Catchment were virtually non-existent (as described in Section 2.12).
- *expanded programs*: actions modelled and / or recommended in this Plan that will further reduce catchment export loads into all the Myall Lakes water bodies beyond that in the existing programs.

In order to estimate the benefits of these possible remediation actions, several scenarios were modelled and compared using the DSS. These essentially compared implementation of these actions with the effects of current programs and the current situation.

Detailed descriptions of scenarios of existing and expanded remediation actions are provided in Appendix 20.

Table 2.15.1. Remediation actions modelled for rural areas of the Myall Lakes catchment.

Actions	Program description
Groundcover management	Groundcover management refers to a sustainable grazing program for landholders, and is focussed on improving groundcover management on pasture lands. It involves field days and formal workshops with experts, developing information and training material on stocking rates, formal training courses such as Prograze, a dung beetle release program, and a program of on-ground works that will assist landholders to better manage their groundcover levels (including off-stream watering, solar pumps and fencing).
Nutrient management (Fertiliser)	Nutrient management is a component of a sustainable grazing program focussed on the appropriate application and storage of nutrients. It involves working with landholders to trial different types of fertilisers, formal training courses such as LANDSCAN, subsidising and promoting the use of soil tests, and providing assistance with interpretation of the tests so that the results can be integrated into a whole-farm plan. This program also supports a dung beetle program – however, it is costed in the groundcover management program. Additional actions related to the management of human and animal effluent include the upgrade of laneways and stock crossings. However, these kinds of actions were not able to be modelled.

Actions	Program description
Infrastructure (Dam) management	Infrastructure management includes the refurbishment of dams that are a water quality risk as well as decommissioning those that are not functioning, and potentially acting as a source of nutrients and sediments to the system. It involves working with landholders to repair dam structural problems, controlling stock access to the dam or providing an alternative stock water supply from the dam. It also involves landholder training, as well as training and accreditation of contractors. Additional actions relating to the management of infrastructure have also been identified, including road and laneway management. However, these kinds of actions were not able to be modelled.
Riparian remediation	Riparian remediation programs include the rehabilitation of sites with active stream bank erosion. These sites are based on identified locations in existing plans, such as rivercare plans. This program includes significant in-stream repair work for bank stabilisation and fencing off the creek in the identified areas.
Unpaved road remediation	This program [pt91]aims to identify and seal unpaved roads in priority areas, such as creek crossings. This would also include installing best practice sediment and erosion control features, such as mitre drains to divert road runoff into grassed areas.

No remediation actions were modelled in urban areas of Myall Lakes. This is because these areas are relatively small contributors to overall water quality, given their small size in the catchment. Protection actions that involve establishing conditions on new developments and redevelopments proposed for Wallis and Smiths lakes as part of the Development Control Plan (DCP) and Local Environment Plan (LEP) are also intended to be used for management of the Myall Lakes catchment (see description of Water Sensitive Development of Greenfield sites, and Water Sensitive Urban Design protection in Table 2.15.2). For new developments, this means that any proposed development, for example at Bulahdelah, will have to comply with the ‘no net increase’ rule. That is, no net increase in pollutants is allowed for the development (based on the pollutant export rates from the land prior to development), as described in Table 2.15.2 – Water Sensitive Development of Greenfield sites.

The impacts of a DCP for redevelopments have not been modelled due to the low redevelopment rates predicted for Bulahdelah. However, it is recommended that this action still be implemented to provide a buffer against future potential deterioration of Myall Lakes (as described in Table 2.15.2 – Water Sensitive Urban Design protection).

In some sub-catchments, forest land (both forestry and other native vegetation) has been identified as a major source of pollutants. However, the management of forestry areas is not within the scope of this Plan, and should be accounted for by other planning and legislative processes (e.g. DECC licensing agreements).

Protection actions considered for the Myall Lakes catchment are shown in Table 2.15.2. The individual impacts of not implementing these actions could not be modelled with the DSS. It is assumed that these actions all contribute to the avoidance of future deterioration. The ‘No Plan’ scenario incorporates a level of deterioration in the catchment that reflects a worsening of conditions if no protection actions or expanded remediation actions are taken over a 30-year trajectory. It is assumed that these actions all contribute to the avoidance of further deterioration. So, in order to estimate the effects of not implementing these protection actions (under the ‘No Plan’ situation), an estimate was made of the amount of degradation that would occur without protection actions being undertaken. It is recommended that these assumptions are reviewed as part of the seven-year review of the Plan and new estimates are made of the scale of protection necessary to avoid deterioration in water quality.

This estimate is based on an extrapolation of past degradation, given model estimates of ‘historic’ loads and the rate at which these have increased in the past.

Detailed descriptions of the scenarios for protection actions are provided in Appendix 20.

Table 2.15.2. Protection actions considered for the Myall Lakes catchment. These actions were not modelled using the DSS.

Program recommended	Program description
Wetland protection[pt92]	Wetland protection involves the acquisition of healthy but threatened wetlands, and undertaking management and / or rehabilitation as required (e.g. fencing off the wetland, establishing property vegetation plans, management plans, reinstating natural hydrology in acid sulfate-affected landscapes). The program also involves assisting landholders to protect natural wetlands, with advice, training and on-ground works to control stock access. More generally, the program involves partnerships with the community, including raising the profile of wetlands and their role in providing environmental services, as well as encouraging participation in management and restoration.
Riparian protection	The riparian protection program involves fencing and / or stock exclusion for areas of remnant riparian revegetation, including off-stream watering and some planting where vegetation requires rehabilitation. It also involves establishing property vegetation plans in areas not suitable for fencing.
Water Sensitive Development of Greenfield sites	Involves establishing and implementing LEP / DCP provisions on Greenfield development sites in the Myall Lakes catchment to enforce ‘no net increase’ in pollutants relative to the existing land use (agricultural and forest land use classifications). This program also involves establishing heads of consideration for voluntary planning agreements with developers.
Water Sensitive Urban Design protection	WSUD protection is an education and capacity-building program on water-sensitive urban design and management of urban land. It involves workshops, field days and demonstration sites with stakeholders including the general community, business, and building and development industries. It involves updating plans, strategies and design guidelines (such as road guidelines), as well as resourcing general sediment and erosion control.

Program recommended	Program description
Best management of unpaved roads	Best management of unpaved roads includes construction of mitre drains to divert road runoff into grassed areas, and sealing and diverting runoff away from streams particularly in the vicinity of creek crossings. The program involves mapping the location and extent of road erosion sites, and undertaking risk analysis in each sub-catchment to prioritise roads for rehabilitation or closure. This program also includes developing and undertaking training and auditing of contractors and council staff specific to road construction to ensure best management practices are applied.
Improved pollution control systems / management systems	Improved management and pollution control systems involves reviewing how water quality management, both within and between organisations, is approached. It focuses on establishing checking and review loops in key areas such as compliance with conditions of consent, and sediment and erosion control, and also highlights the need to embed water quality improvement actions in organisational plans to ensure the WQIP is implemented. It highlights the need to review a range of existing systems such as the fee structure for on-site sewage management, and recommends exploring alternative ways to formalise the response to complex pollution cases and strengthen cross-agency relationships and delegation.
Improved management of lake use activities	Improved management of lake use activities involves establishing markers to protect macrophyte beds, upgrading gravel boat ramps, assessing the impact of water sports and adopting no-discharge guidelines for greywater.

In this exploratory analysis, two alternative futures are considered:

- No Plan – no implementation of protection actions and only implementation of existing remediation actions
- WQIP – implementation of all protection actions and implementation of expanded remediation actions.

A trajectory of impacts over seven years is used to demonstrate the benefits of implementing protection and expanded remediation actions as part of the WQIP, compared with the current 'No Plan' condition as above. Many of the actions identified in the Plan are designed to be implemented over more than seven years (e.g. Wetland protection and Water Sensitive Development of Greenfield sites) – in these cases, the impact at seven years assumes that implementation of these actions is in progress, rather than completed.

Table 2.15.3. Scenario trajectories with (WQIP) and without (No Plan) the implementation of the Water Quality Improvement Plan. Existing programs refer to the full implementation of remediation actions planned and commenced prior to the development of this Plan. Expanded programs were developed for this Plan to further reduce nutrient and sediment inputs into the Myall Lakes system, and are remediation actions. Both types of programs were modelled in this Plan. Protection actions were not modelled in this Plan.

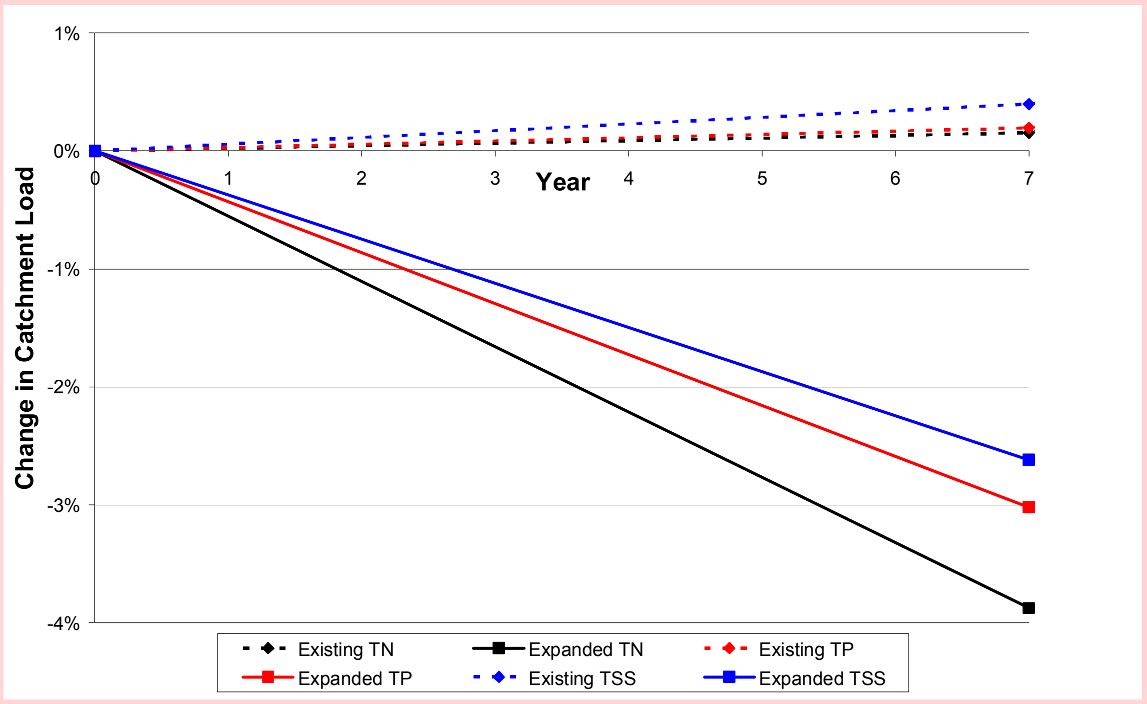
	Year 0	**Year 7**	
		No Plan	**WQIP**
Remediation actions			
Nutrient management (Fertiliser)	Existing situation	Existing programs [a]	Expanded programs
Groundcover management	Existing situation	Existing programs	Expanded programs
Infrastructure (Dam) management	Existing situation	Existing programs	Expanded programs
Riparian remediation	Existing level	Existing level	Seven years of works
Unpaved road remediation	Existing situation	No works	Seven years remediation
Protection actions			
Water Sensitive Redevelopment	Existing situation	-- [b]	--[DG93] [b]
Riparian protection	Existing situation	Loss of healthy riparian vegetation	No loss of healthy riparian vegetation
Wetland protection	Existing situation	Loss of healthy wetlands	No loss of healthy wetlands
Water Sensitive Development of Greenfield sites	Existing situation	Lower levels of controls	No net increase
Water Sensitive Urban Design protection	Existing situation	Seven years without protection	Seven years with protection
Improved pollution control systems / management systems	Existing situation	Seven years without improved systems	Seven years with improved systems
Best management practice of unpaved roads	Existing situation	Seven years without improved systems	Seven years with improved systems
Improved management of lake use activities	Existing situation	Seven years without improved systems	Seven years with improved systems

a: At the time of writing this Plan, the existing programs in the Myall Lakes catchment were virtually non-existent.
b: No modelled scenarios were run for this management action, as predicted redevelopment rates were low for Bulahdelah and any redevelopment with improved controls would create a buffer to protect the lakes.

2.15.1.2 Catchment exports

The percentage change in TN, TP and TSS loads for the entire Myall Lakes catchment in the 'No Plan' and 'WQIP' alternative futures, as defined in Table 2.15.3, is shown in Figure 2.15.1. The 'No Plan' scenario incorporates a level of deterioration in the catchment that reflects a worsening of conditions if no protection actions or expanded remediation actions are taken over a seven-year trajectory. Full implementation of the protection actions is assumed to prevent any deterioration in the current condition of the Myall Lakes catchment and estuary.

For all pollutants, this deterioration is not halted by fully implementing existing remediation programs. The effectiveness of existing remediation programs is higher for TP and TSS than TN. Consequently, more TP and TSS is captured than TN by implementing the existing remediation programs. Figure 2.15.1 shows that full implementation of protection and seven years implementation of expanded remediation actions in the WQIP reduces catchment exports from current levels by 3.9% (TN), 3.0% (TP) and 2.6% (TSS).



[DG94]

Figure 2.15.1. Percentage change in catchment exports of TN, TP and TSS in the Myall Lakes under the No Plan (no protection actions and existing remediation actions only) and WQIP (full implementation of protection actions and expanded remediation actions) alternative futures. A negative value indicates a reduction in catchment exports.

Percentage load reductions under the WQIP scenario vary across sub-catchments, which largely reflect differences in land use (Table 2.15.4). Significant reductions in TN, TP and

TSS are predicted for sub-catchments draining into the Bombah Broadwater (particularly the Upper Myall River and Crawford River sub-catchments), reflecting the land use (which is predominately agriculture) and size of the catchment area. Smaller reductions are estimated for Myall Lake and Boolambayte Lake, corresponding to the relatively less-disturbed nature of these sub-catchments (and therefore where there is less land to target with the remediation actions). This is reflected in the relative contribution of the sub-catchments to the change in total catchment loads. Bombah Broadwater is the receiving waters for the Upper Myall River, Crawford River, Bombah Broadwater, and Lower Myall River sub-catchments, which together account for 78% (TN), 83% (TP) and 81% (TSS) of the reductions in catchment loads. The Bombah Broadwater was identified earlier in this Plan as that part of the whole Myall Lakes system requiring the most change to return it to *High conservation value* condition (Section 2.13.3).

Table 2.15.4. Percentage change in loads from the modelled sub-catchments and the whole Myall Lakes catchment achieved after seven years implementation of the WQIP (assumption of all protection actions preventing further deterioration, and modelled impacts of expanded remediation actions). A negative '% change in load' indicates a decrease in exports with implementation of the remediation actions.

Sub-catchment	% change in load			% of total catchment change in load		
	TN	TP	TSS	TN	TP	TSS
Myall Lake	-2.2	-2.0	-1.9	10	10	11
Boolambayte Lake	-1.7	-1.8	-1.6	11	6	7
Upper Myall River	-6.1	-6.6	-3.7	44	28	51
Crawford River [a]	-4.2	-7.3	-4.5	14	18	4
Bombah Broadwater	-3.3	-2.8	-0.7	12	16	10
Lower Myall River	-2.4	-1.2	-2.8	8	21	16
Whole Myall Lakes catchment [b]	-3.9	-3.0	-2.6			

a: Actions defined for the Crawford River do not include the actions defined in the Crawford Drinking Water Strategy. These strategies are considered in isolation and reported in Appendix 21.
b: This row reflects the percentage improvement to total catchment export loads resulting from implementation of all actions in all sub-catchments. This corresponds to the percentage reductions in Figure 2.15.1 for 'expanded' TN, TP and TSS.

Figure 2.15.2 demonstrates the relative effectiveness of the modelled expanded remediation actions on pollutant exports for the whole Myall Lakes catchment. Of the actions, groundcover management accounts for about half the TN and TP load reductions, and 93% of the TSS load reductions. Nutrient management has a large impact on TN and TP exports. Dam remediation or removal and riparian remediation activities have little influence on exports at a catchment scale. Figures 2.15.3 to 2.15.8 show the relative effectiveness of these programs by sub-catchment. These results by sub-catchment largely support the whole-of-catchment results, although there are differences in what each program can achieve in individual sub-catchments.

The modelled actions target agricultural lands – which comprise 19% of the area and contribute 31% of the TN, 24% of the TP and 47% of the TSS loads from the whole Myall Lakes catchment – as well as unpaved roads in the Crawford River sub-catchment. This means that the bulk of the pollutants sourced from the catchment will not be mitigated by the modelled remediation actions. Some of these pollutants will be ‘background’ levels sourced from relatively unmodified land uses (e.g. protected vegetation), although there is still scope to develop further remedial actions on review of the Plan. Section 2.15.1 identified actions that were modelled as well as those that could not be modelled for specific reasons (e.g. data or model limitations, perceived to be minor importance, not in CCI focus area). It is likely that further reductions in catchment loads could be made by addressing other remedial actions that are not modelled in this Plan, such as implementation of best management practice for unpaved roads.

A summary of the relative land use contributions to sub-catchment pollutant loads is given in Appendix 19. The major contributors of pollutants in the Bombah Broadwater, Lower Myall River and Crawford river sub-catchments that could be targeted by remedial works are unpaved roads and agricultural lands. The major contributors of pollutants in the Myall Lake sub-catchment that could be targeted by remedial works are unpaved roads. The major contributors of pollutants in the Upper Myall River sub-catchment that could be targeted by remedial works are from agricultural lands, with lesser contributions from unpaved roads and urban residential land. The major contributors of pollutants in the Lower Myall River sub-catchment that could be targeted by remedial works are agricultural and urban residential lands.

Agricultural lands are well-targeted in this Plan for all the Myall Lakes sub-catchments. Road remediation actions were applied only to the Crawford River sub-catchment and this treatment substantially reduced TSS loads (13% reduction) from the sub-catchment.[17,18] To further protect Myall Lake and Boolambayte Lake, and improve conditions in Bombah Broadwater, additional reductions in catchment loads could be achieved by undertaking actions relating to unpaved roads, especially in identified ‘hot spots’ adjacent to the lake or drainage / creek lines. Additional improvements may be achieved in all sub-catchments (including the Crawford River sub-catchment) by implementing best management practices on roads. As outlined in the Action Plan for Rural Road Management (Section 3.3.3), a key area for future investigation should be the

17 Road remediation was identified as an issue by the Advisory Committee throughout the CCI project. Limitations in data suitable for the development of the rural water quality model (AnnAGNPS) meant that this model, and therefore the DSS, were limited to coarse assessments of sediment and nutrients sourced from roads. They are not capable of modeling, for example, the impacts of best management practices within the time frame of the development of the Plan. Implementing these would be expected to decrease sediment and nutrient exports from roads, which would have beneficial impacts on ecological condition of the whole Myall Lakes system, and more pronounced impacts on the creeks and rivers that receive runoff from roads.

18 The Advisory Committee identified the Crawford River sub-catchment as of importance with respect to erosion from unpaved roads. The decision was made to model the road remediation actions only in the Crawford River sub-catchment. Given this scenario definition, the remediation of unpaved roads has a negligible modelled impact on the whole Myall Lakes catchment loads (<1%). Implementing road remediation actions across the whole Myall Lakes catchment would have beneficial impacts through further reductions in sediment exports from roads (although at a substantial monetary cost). In sub-catchments where unpaved roads dominate sediment loads (e.g. the Myall Lake sub-catchment), remediation of roads should be considered when implementing the WQIP.

mapping of the location and extent of road erosion sites, and undertaking risk analysis in each sub-catchment (Section 3.3.3).

Urban remediation actions, such as the implementation of water-sensitive urban devices, should be considered for urban land in the Myall Lakes sub-catchments. The limited extent of urban lands upstream of Bombah Broadwater means that reductions in urban pollutant loads will not constitute a large proportion of the total loads entering Bombah Broadwater. However, given the amount of improvement required to move towards *High conservation value* in the Bombah Broadwater, all opportunities to improve water quality should be considered when implementing the Plan. Implementing remedial actions for residential areas at Hawks Nest and Tea Gardens may also further reduce Lower Myall River sub-catchment loads, with consequent benefits to the Lower Myall River. It is not likely that actions undertaken in Hawks Nest and Tea Gardens will improve the condition of the Bombah Broadwater, given the length of the Myall River and the overall net flow of water out of the Bombah Broadwater.

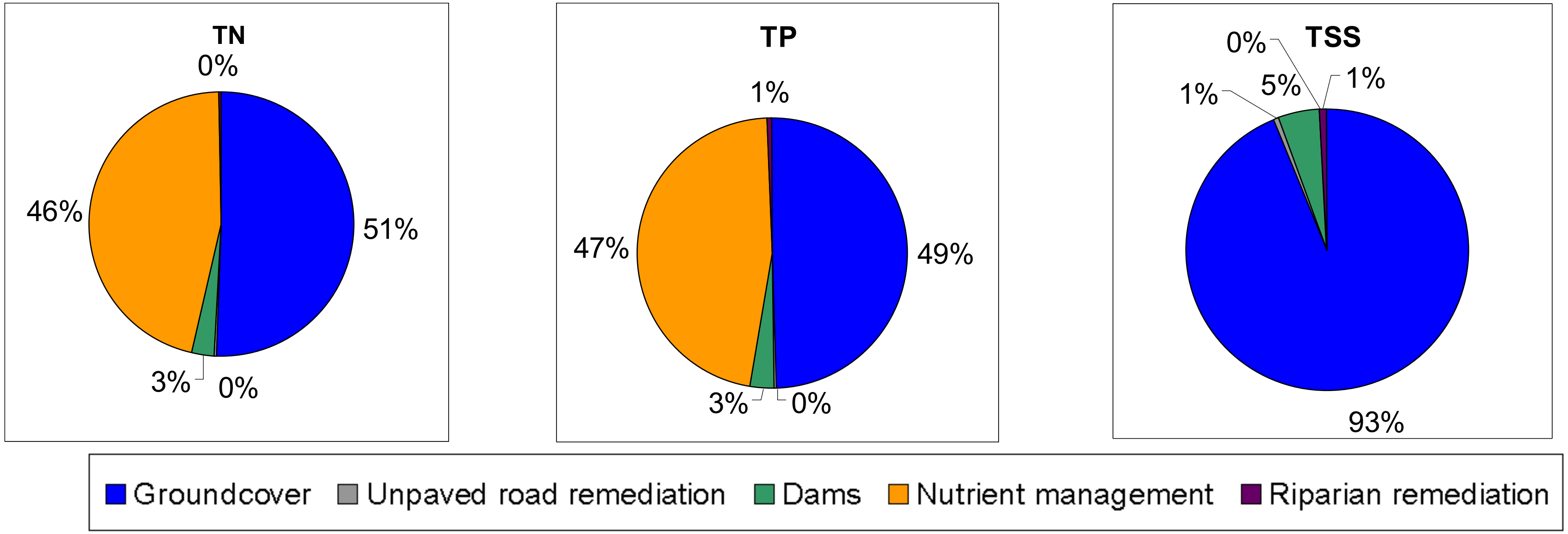


Figure 2.15.2. Relative modelled impact of expanded remediation actions for the whole Myall Lakes catchment with implementation of the WQIP.

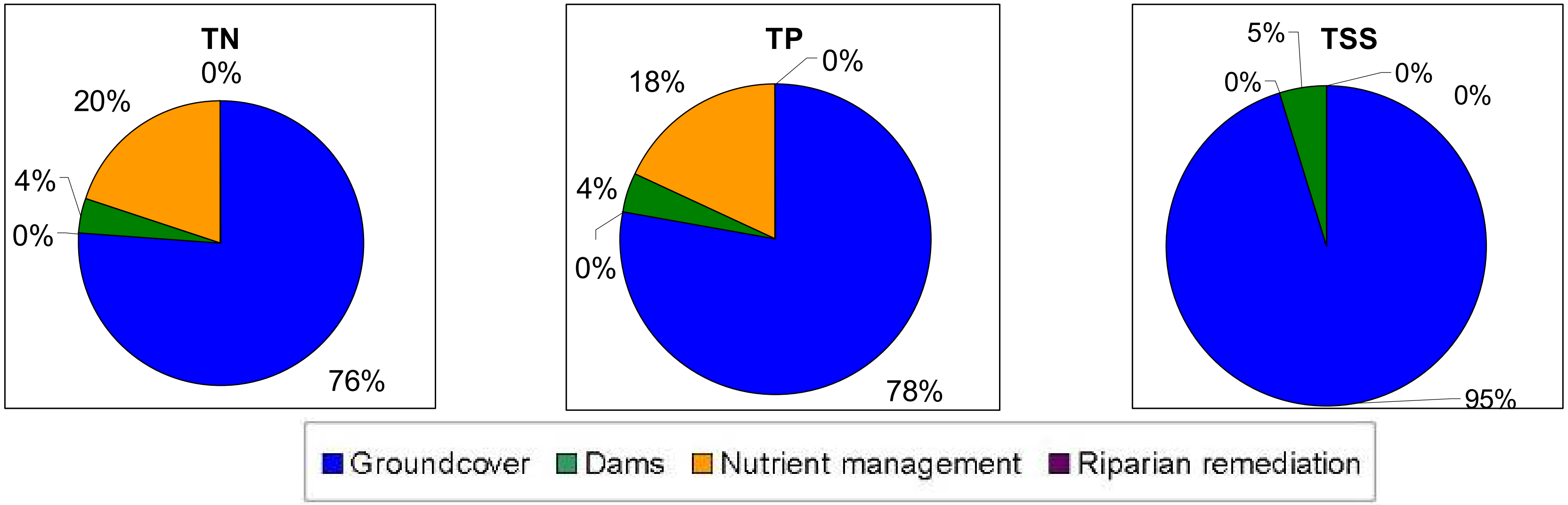


Figure 2.15.3. Relative modelled impact of expanded remediation actions for the Myall Lake sub-catchment with implementation of the WQIP.

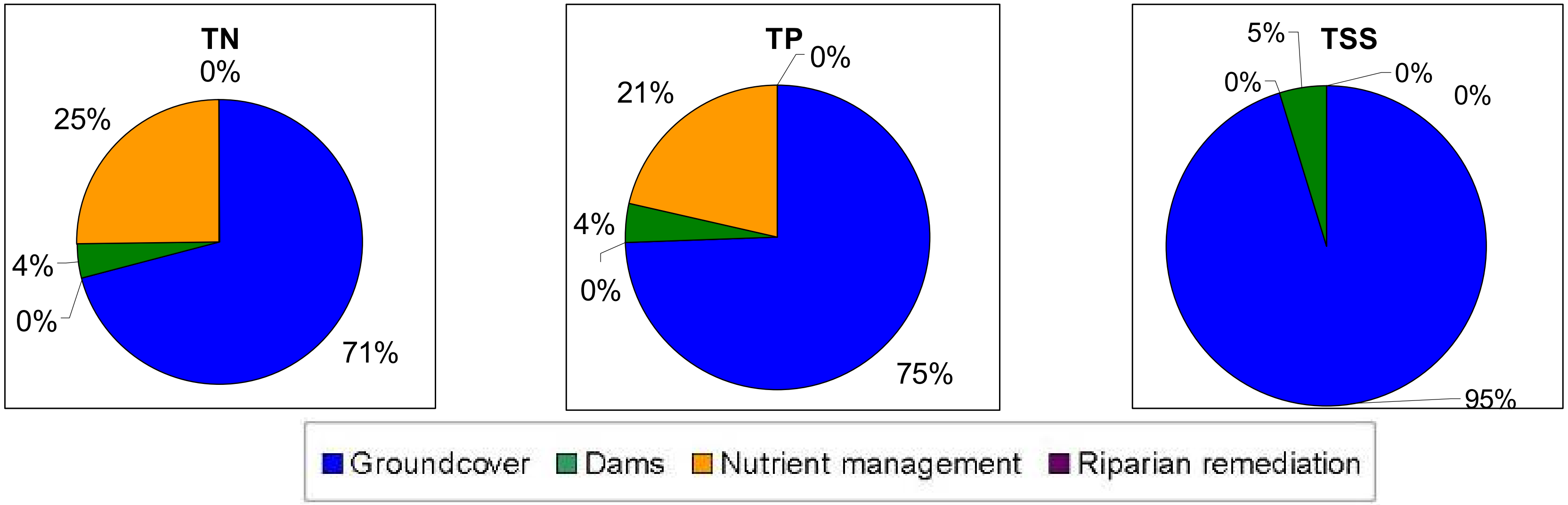


Figure 2.15.4. Relative modelled impact of expanded remediation actions for the Boolambayte Lake sub-catchment with implementation of the WQIP.

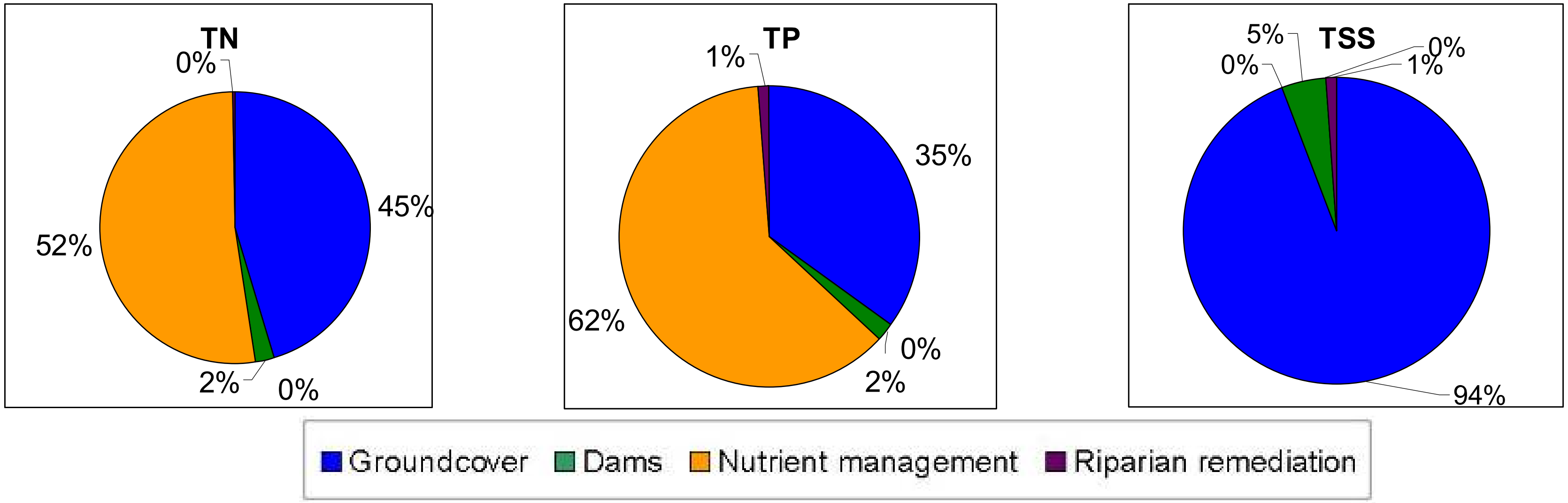


Figure 2.15.5. Relative modelled impact of expanded remediation actions for the Upper Myall River sub-catchment with implementation of the WQIP.

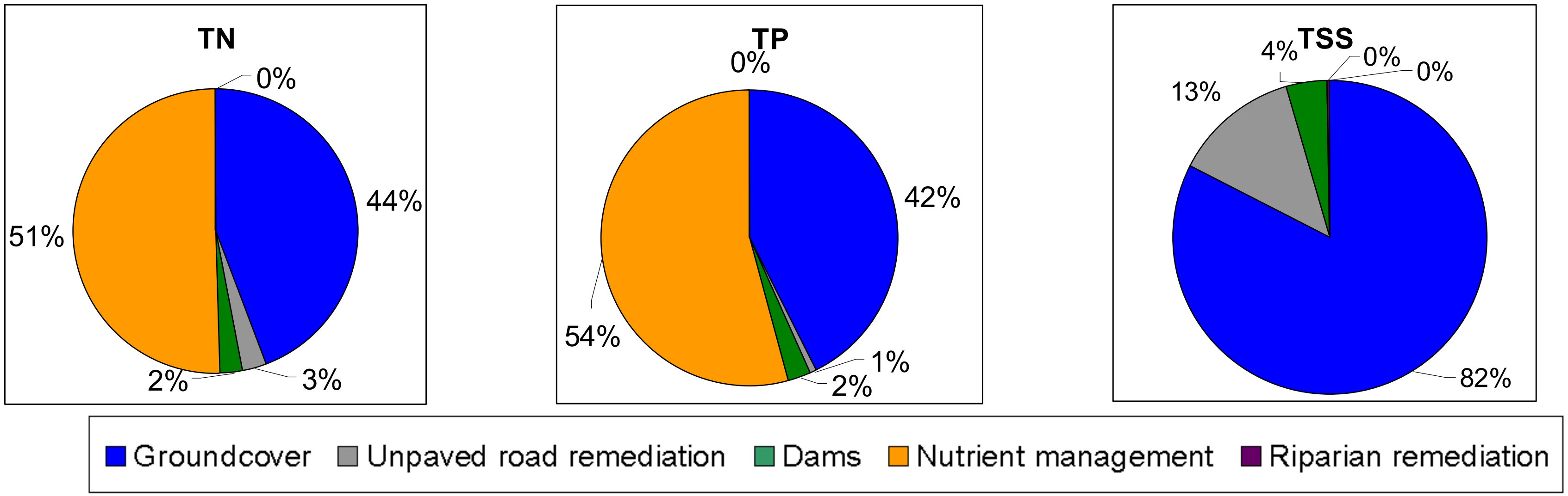


Figure 2.15.6. Relative modelled impact of expanded remediation actions for the Crawford River sub-catchment with implementation of the WQIP.

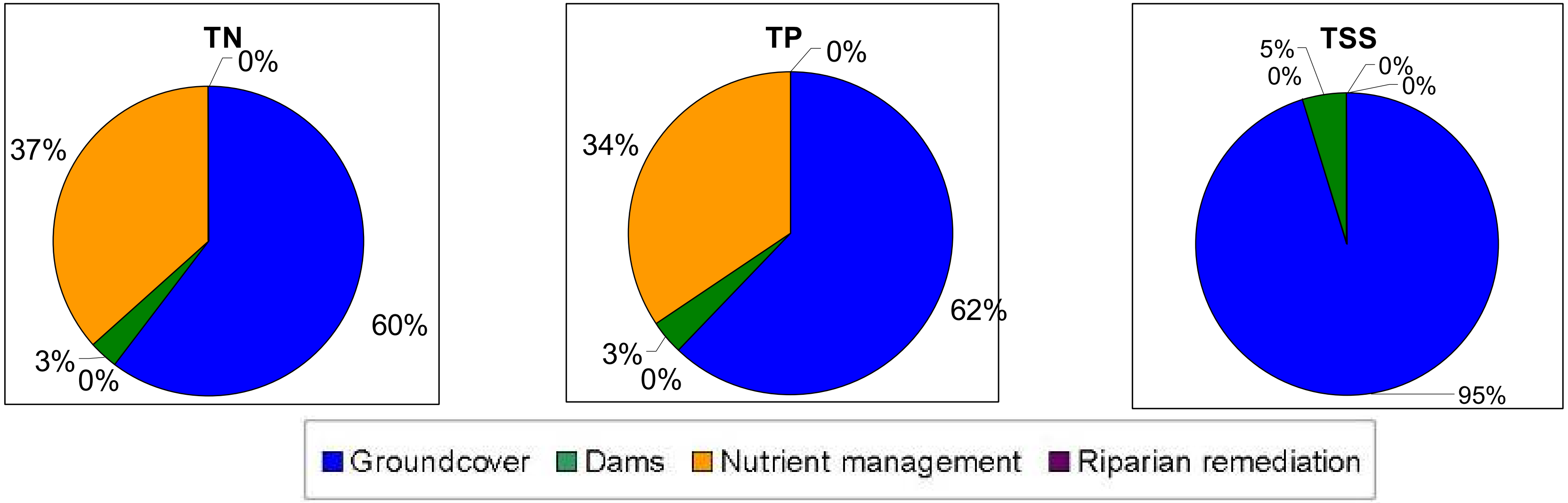


Figure 2.15.7. Relative modelled impact of expanded remediation actions for the Bombah Broadwater sub-catchment with implementation of the WQIP.

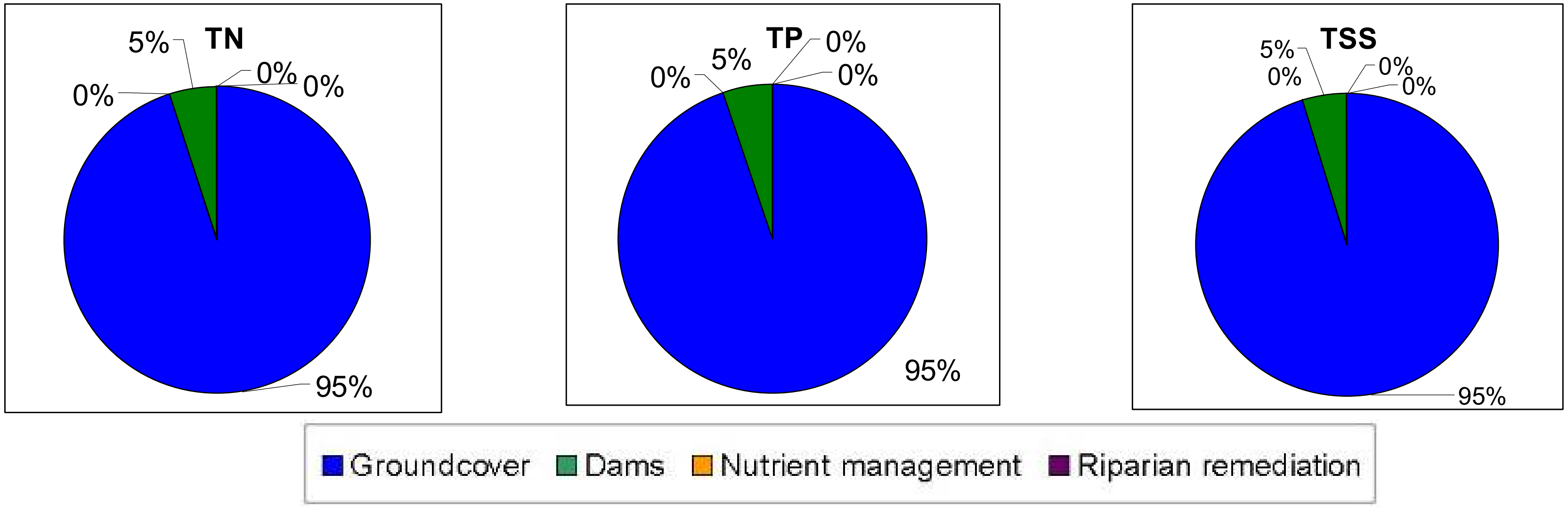
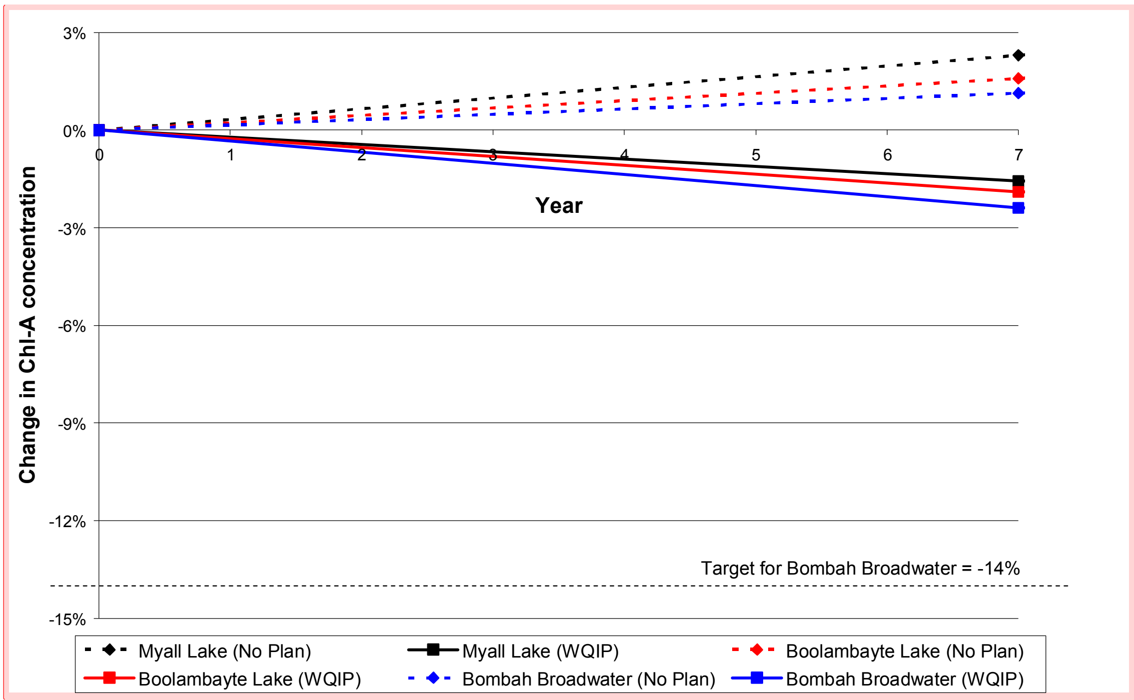


Figure 2.15.8. Relative modelled impact of expanded remediation actions for Lower Myall River sub-catchment with implementation of the WQIP.

2.15.1.3 Estuary condition

The percentage reductions in chlorophyll-a concentrations in the Myall Lakes with implementation of the WQIP are shown in Figure 2.15.9.

Figure 2.15.9 shows that reductions in chlorophyll-a concentrations of 2.4% are achieved in the Bombah Broadwater with full implementation of protection actions in the WQIP and seven years of implementation of the expanded remediation actions. Smaller reductions are achieved for Boolambayte Lake (1.9%) and Myall Lake (1.6%). Changes do not reach the 14% reduction identified as the long-term Ecological Condition Target for the Bombah Broadwater.



[DG95]

Figure 2.15.9. Percentage change in chlorophyll-a achieved in the Myall Lakes under the No Plan (no protection actions and existing remediation actions only) and WQIP (full implementation of protection actions and expanded remediation actions) alternative futures. A negative value indicates an improvement in conditions in the water body, as chlorophyll-a levels decrease.

While these changes do not fully achieve targets for the Bombah Broadwater, they are an important step in moving towards these outcomes. If the WQIP is not implemented, the deterioration in chlorophyll-a levels presented in Figure 2.15.9 would increase the intensity and frequency of major and minor algal blooms occurring in the Myall Lakes system. Given the magnitude of the changes predicted, if the WQIP is implemented, generally we would not expect to see much difference from the current situation in the overall health of the system. However, by implementing the Plan there would be a reduction in the risk, frequency and severity of algal blooms. Importantly under the WQIP, the protection actions and expanded remediation actions would result in no further decline in lake condition, and all lakes and rivers would improve in condition to varying degrees. Myall Lake and

Boolambayte Lake would also continue to achieve their *High conservation value* status and their target of no further decline.

2.15.1.4 Costs of modelled remediation actions

The cumulative costs of implementing and maintaining the modelled expanded remediation actions (groundcover, nutrient management, dams, riparian remediation, and unpaved road remediation) across the catchment over the seven-year trajectory are shown in Figure 2.15.10. Details of the assumptions used to define these figures are provided in Appendix 20. Groundcover and dam remediation and removal actions are the most expensive options. Riparian 'hot spot' remediation is the cheapest option. This reflects the relatively few riparian hot spots identified in the Upper Myall River and not the cost-effectiveness of the riparian remediation action. The expense of the groundcover and dam remediation actions reflects the need for ongoing program costs over the period of this Plan (Appendix 20). Unpaved road remediation has a smaller overall cost than these two options, but is more expensive overall than nutrient management or riparian remediation.

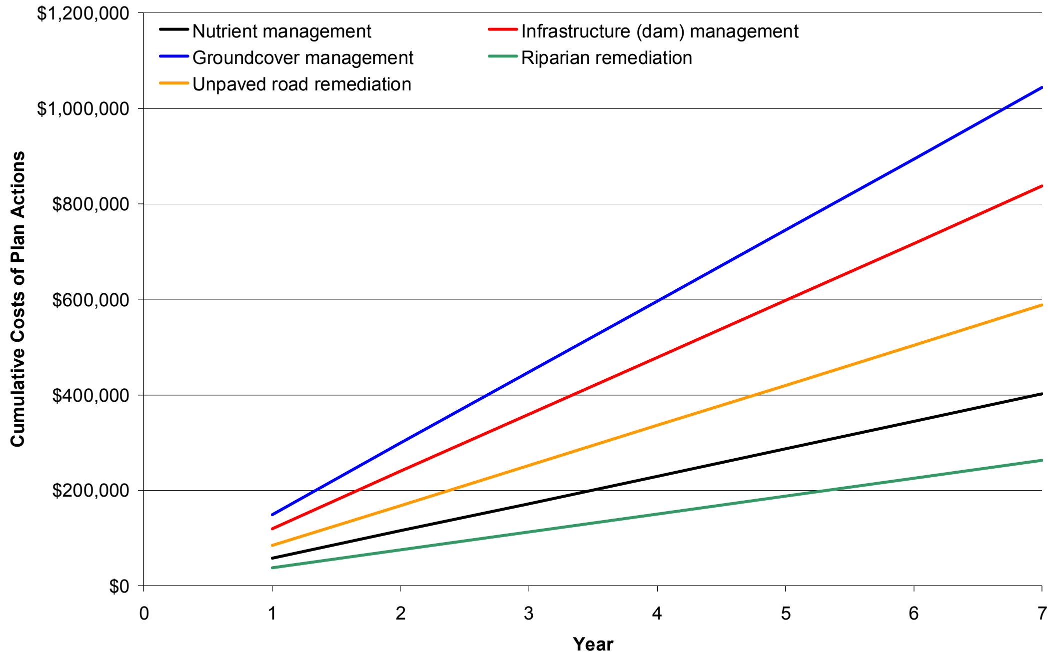


Figure 2.15.10. Cumulative costs of potential rural WQIP actions.

Even though the overall costs of groundcover management are shown to be the highest, the cost per unit of load of catchment export controlled by each action in Table 2.15.5 illustrates that this program is a cost-effective means of reducing pollutant loads from rural areas. Unpaved road remediation, riparian remediation and infrastructure (Dam) management programs are the least cost-effective, as they have a large cost to implement and maintain, and also do not show significant impacts at the catchment scale or in the estuary. However, this does not account for risks of one-off extreme events, such as the potential localised risks of dam failure similar to the situation seen in Coomba Bay (where

25 ha of seagrass was smothered by a single dam failure). While this action is seen as a remediation action, it is also having a protective effect against localised impacts of dam failure.

Table 2.15.5. Cost ($) per unit of load controlled by modelled rural remediation actions applied across the Myall Lakes catchment. A unit is 1 kg for TN and TP, and 1 tonne for TSS.

	Nutrient management (Fertiliser)	Groundcover management	Riparian remediation	Infrastructure (Dam) management	Unpaved road remediation
TN	$400	$918	$23,628	$12,515	$52,765
TP	$3,181	$7,926	$98,054	$103,870	$437,940
TSS	$0	$3,828	$89,881	$57,127	$200,717

This analysis does not account for the improvements that the full implementation of WQIP protection and expanded remediation actions generate in the rivers and creeks. Previous studies have shown the importance of healthy riparian vegetation – and limiting sediment and nutrient inputs to creeks and rivers – for maintaining stream water quality, habitats and fish communities in associated aquatic ecosystems (Growns, Pollard & Gehrke 1998; Pusey & Arthington 2003; Wang, Lyons & Kanehl 2002). These improvements are likely to be substantial and highly valued. The value of these improvements was estimated as part of a benefit-cost analysis undertaken by Gillespie Economics (Appendix 15). Section 2.15.3 summarises the results of the benefit-cost analysis for the Myall Lakes Plan.

The costs analysed above consider only those remediation actions that were modelled using the DSS. For actions that were not modelled, costs are outlined in Section 2.15.2, and the costs and benefits of implementing the actions are considered in Section 2.15.3.

2.15.2 Summary of recommended programs for protection, remediation and management support of Myall Lakes

A brief description of the programs recommended as part of this plan for protection, remediation and management support of the Myall Lakes catchment are given in Table 2.15.6. Management support programs are those recommended to support the implementation of protection and remediation actions in the Myall Lakes Plan, and include adaptive management strategies, ecological monitoring and future investigations relating to the Farm Scale Action Plan. Management support actions do not lend themselves to having their impacts estimated using biophysical models, so have not been modelled.

The resources required and activities undertaken as part of these remediation, protection and management support programs are also summarised in Table 2.15.6. Full details of assumptions behind these recommendations are given in Appendix 20. More detail on the farm-scale actions that underpin the programs described are outlined in Section 3.3.

Note that it is recommended that the rural programs described below should be considered in the 'whole-farm approach' described in Section 3.3 (and not implemented in isolation).

Table 2.15.6. Summary of recommended programs in the Myall Lakes: Protection, remediation and management support.

Program	Program description	Resources	Details
Remediation activities – modelled using DSS			
Groundcover management	Groundcover management refers to a sustainable grazing program for landholders, and is focussed on improving groundcover management on pasture lands. It involves field days and formal workshops with experts, developing information and training material on stocking rates, formal training courses such as Prograze, a dung beetle release program, and a program of on-ground works that will assist landholders to better manage their groundcover levels (including off-stream watering, solar pumps and fencing).	• 1.5 x Catchment officer providing one-to-one advice and extension activities • Landholder training courses • Field days • Workshops • Dung beetle release • Provision of off-stream water and fencing	Section 3.3.2, Appendix 20
Nutrient management (Fertiliser)	Nutrient management is a component of a sustainable grazing program focussed on the appropriate application and storage of nutrients. It involves working with landholders to trial different types of fertilisers, formal training courses such as LANDSCAN, subsidising and promoting the use of soil tests, and providing assistance with interpretation of the tests so that the results can be integrated into a whole-farm plan. This program also supports a dung beetle program – however, it is costed in the groundcover management program. Additional actions related to the management of human and animal effluent include the upgrade of laneways and stock crossings. However, these kinds of actions were not able to be modelled.	• 0.33 x Catchment officer providing one-to-one advice and extension activities • Landholder training courses • Soil tests	Section 3.3.2, Appendix 20
Infrastructure (Dam) management	Infrastructure management includes the refurbishment of dams that are a water quality risk as well as decommissioning those that are not functioning, and potentially acting as a source of nutrients and sediments to the system. It involves working with landholders to repair dam structural problems, controlling stock access to the dam or providing an alternative stock water supply from the dam. It also involves landholder training, as well as training and accreditation of contractors. Additional actions relating to the management of infrastructure have also been identified, including road and laneway management. However, these kinds of actions were not able to be modelled.	• 0.75 x Catchment officer providing one-to-one advice and extension activities • 0.375 x Technical officer • Workshops • On-ground works (dam repair or decommissioning)	Section 3.3.2, Appendix 20

Program	Program description	Resources	Details
Riparian remediation	Riparian remediation programs include the rehabilitation of sites with active stream bank erosion. These sites are based on identified locations in existing plans, such as rivercare plans. This program includes significant in-stream repair work for bank stabilisation and fencing off the creek in the identified areas.	• 0.24 x Catchment officer providing one-to-one advice and extension activities • Fencing, replanting, engineering works as appropriate • Provision of off-stream water	Section 3.3.2, Appendix 20
Protection actions – estimate of combined effect of protection programs estimated based on past degradation. No split of impacts between actions able to be provided. This was not modelled using the DSS.			
Water Sensitive Redevelopment	Water Sensitive Redevelopment involves the implementation of a development control plan that specifies best practice water-sensitive urban design (including biofiltration and rainwater tanks) on all redevelopments. The program of redevelopment has been estimated based on existing redevelopment rates.	• No scenarios were modelled for Bulahdelah, as predicted redevelopment rates were low and any redevelopment with improved controls would create a buffer to protect the lakes	Section 3.4.2, Appendix 20
Wetland protection	Wetland protection involves the acquisition of healthy but threatened wetlands, and undertaking management and / or rehabilitation as required (e.g. fencing off the wetland, establishing property vegetation plans, management plans, reinstating natural hydrology in acid sulfate-affected landscapes). The program also involves assisting landholders to protect natural wetlands, with advice, training and on-ground works to control stock access. More generally, the program involves partnerships with the community, including raising the profile of wetlands and their role in providing environmental services, as well as encouraging participation in management and restoration.	• Acquisition of 451 ha of wetlands including fencing and property vegetation plans as required	Appendix 20
Riparian protection	The riparian protection program involves fencing and / or stock exclusion for areas of remnant riparian revegetation, including off-stream watering and some planting where vegetation requires rehabilitation. It also involves establishing property vegetation plans in areas not suitable for fencing (e.g. high-slope areas).	• 0.5 x Catchment officer to manage program per year • Protection of 720 km of remnant riparian vegetation • Fencing and Property Vegetation Plan as appropriate (estimate 70:30) • Provision of off-stream water	Section 3.3.2, Appendix 20

Program	Program description	Resources	Details
Water Sensitive Development of Greenfield sites	Water Sensitive Development of Greenfield sites involves establishing and implementing LEP / DCP provisions on Greenfield development sites in the Myall Lakes catchment. This will involve enforcing 'no net increase' in pollutants relative to the existing land use (agricultural and forest land use classifications). This program also involves establishing heads of consideration for voluntary planning agreements with developers.	• Acquisition and annual maintenance costs for WSUD devices • Staff and consultant time to implement programs	Section 3.4.2, Appendix 20
Water Sensitive Urban Design protection	WSUD protection is an education and capacity-building program on water-sensitive urban design and management of urban land. It involves workshops, field days and demonstration sites with stakeholders including the general community, business, and building and development industries. It involves updating plans, strategies and design guidelines (such as road guidelines), as well as resourcing a sediment and erosion control audit and training program.	• Council staff to deliver education and capacity-building programs, including training and audits	Section 3.4.2, Appendix 20
Best management of unpaved roads ~	Best management of unpaved roads includes construction of mitre drains to divert road runoff into grassed areas, and sealing and diverting runoff away from streams particularly in the vicinity of creek crossings. The program involves mapping the location and extent of road erosion sites, and undertaking risk analysis in each sub-catchment to prioritise roads for rehabilitation or closure. A program of training and auditing contractors and council staff specific to road construction to ensure best management practices are applied will also be undertaken as part of this action.	• Staff and consultant time for training and education program • Note this program does not cover the cost of undertaking best practice, as they are covered with routine road maintenance	Section 3.3.3
Improved management of lake use activities	Improved management of lake use activities involves reviewing stormwater management plans, investigating other management issues and options such as establishing markers to protect macrophyte beds, upgrading gravel boat ramps, assessing the impact of water sports and adopting 'no discharge' guidelines for greywater.	• Staff and consultant time • On-ground works	Section 3.5.2, Appendix 20

Program	Program description	Resources	Details
Improved pollution control systems / management systems	Improved management and pollution control systems involves reviewing how water quality management, both within and between organisations, is approached. It focuses on establishing checking and review loops in key areas, such as compliance with conditions of consent, and sediment and erosion control, and also highlights the need to embed water quality improvement actions in organisational plans to ensure the WQIP is implemented. It highlights the need to review a range of existing systems such as the fee structure for on-site sewage management, and recommends exploring alternative ways to formalise the response to complex pollution cases and strengthen cross-agency relationships and delegation.	• Council and state government agency staff time • Costs of development of GIS-based data base	Section 3.7, Appendix 20
Management support actions – not modelled in the DSS			
Adaptive Management Strategy / Ecological monitoring program	The Adaptive Management Strategy underpins the implementation of the WQIP. It highlights the ecological, political and social uncertainties surrounding the WQIP, and identifies ways to track these and make informed management decisions during Plan implementation. The ecological monitoring program outlined in the strategy involves the collection of data on ecological indicators such as chlorophyll-a, water clarity, habitat assessments on river reaches and fish sampling. The strategy also recommends a public reporting regime for the WQIP.	• 0.05 x Council staff to do the reporting and collating for the WQIP • Specialist assistance for establishing the WQIP monitoring program – Staff time • Equipment hire	Section 3.9 Appendix 30
Future investigation relating to the Farm Scale Action Plan[DG96]	Specific areas for future investigation that relate to improving farm management practices are undertaken through this program. Areas for investigation include riparian management, wetland management, groundcover management, farm infrastructure management, nutrient management and ways to encourage uptake of improved management practices. The findings from this research are applicable across all three catchments (Wallis, Smiths and Myall lakes). ~[DG97]	• Researcher and specialist time	Section 3.3.2

~ Due to the high cost of road remediation and the negligible modelled impact on the whole Myall Lakes catchment loads (<1%), road remediation has not been recommended for the Myall Lakes. Under best management practice of unsealed roads, further research to identify hot spot areas is required. In sub-catchments where unpaved roads dominate sediment loads (e.g. Myall Lake sub-catchment, Crawford sub-catchment), remediation of roads should be considered when implementing the WQIP.[pt98]

Responsibility for implementing these programs is outlined in Section 3.

Total costs over the seven years of the Plan for protection, remediation and management support actions are summarised in Table 2.15.7. These costs assume seven years of implementation of all the actions.

Table 2.15.7. Summary of total costs of protection, remediation and management support options recommended for the Myall Lakes at seven years.

Action	Cost
Remediation actions	
Groundcover management	$1,043,000
Nutrient management (Fertiliser)	$401,000
Infrastructure (Dam) management	$837,000
Riparian remediation	$263,000
Protection actions	
Water Sensitive Redevelopment	~
Wetland protection	$1,809,000
Riparian protection	$881,000
Water Sensitive Development of Greenfield sites	$1,119,000
Water Sensitive Urban Design protection	$43,000[pt99]
Best management of unpaved roads *	$89,000[pt100]
Lake use activities	$143,000
Improved pollution control systems / management systems	$37,000
Management support actions	
Adaptive Management Strategy	$24,000
Ecological monitoring	$122,000
Future investigation relating to the Farm Scale Action Plan	$342[pt101],000
Total	**$7,153,000[DG102]**

~ It is predicted that the redevelopment rates in the Myall Lakes will be low and have therefore not been costed here.

* The costs specified for the best management of unpaved roads covers the cost of establishing new auditing and training program, and identifying areas for rehabilitation. The actual cost of rehabilitation has not been costed here. Neither has the cost of implementing best practice management, as it is assumed that best practice should currently be undertaken.

Table 2.15.7 shows that protection actions are expected to cost a similar amount to groundcover management and infrastructure management. The Plan for the Myall Lakes catchment costs in total approximately $7,153,000 [DG103]over seven years. Note that no discounting has been used to account for costs incurred in later years. This means that the net present value of these costs is less than is shown here.

Refer to section 2.15.1.3 to see the ecological condition and load reductions achieved for full implementation of these expanded remediation actions and all protection actions.

2.15.3. Summary of benefit-cost analysis results for Myall Lakes Plan

Gillespie Economics conducted a benefit-cost analysis for the Myall Lakes management actions. To undertake this type of analysis it was necessary to cost the implementation of the plan over a 30-year period. While the Plan does not present the 30-year figures, this section is intended to provide indicative benefit-cost for future implementation. This section summarises the results of this analysis. Table 2.15.8 lists the potential costs and benefits identified in the analysis of the implementation of the Myall Lakes Plan.[19] Full details of assumptions made and methods used for estimates of the benefit-cost results presented here can be found in Appendix 15. The actual costs associated with the identified programs are detailed in Appendix 20.

Table 2.15.8. Costs and benefits for the Myall Lakes management actions.

Costs	Benefits
Direct program costs	***Direct program benefits***
• Fertiliser	• Increase in area of estuary in good health
• Dams	• Increase in length of river in good health
• Groundcover	• Increased area of native vegetation conservation
• Riparian remediation	• Increased area of wetland conservation
• Greenfields	• Benefits to non-market recreation
• Riparian protection	• Benefits to commercial recreation
• Wetland protection	• Reduced water treatment costs of mid-coast water
Indirect program costs	***Indirect program benefits***
• Opportunity costs of riparian revegetation and protection	• Reduced fertiliser costs and increased productivity of agricultural land
• Costs of alternative water supplies where dams are eliminated	• Increased agricultural productivity where dams are eliminated

Two decision criteria for assessing the economic desirability of a project to society were considered in this analysis:

- *Net present value*: the sum of the discounted benefits less the sum of the discounted costs. A positive net present value indicates that it would be desirable from an economic perspective for society to allocate resources to the project, because the community as a whole would obtain net benefits from the project
- *Benefit-cost ratio*: the sum of discounted benefits divided by the sum of discounted costs. A benefit-cost ratio greater than 1 indicates that the investment is economically efficient and hence desirable from an economic perspective.

19 Protection actions for unpaved roads were not included as part of the benefit-cost analysis.

Calculations of both net present value and benefit-cost ratio indicate that the Plan is economically efficient and desirable from a community perspective (Appendix 15). Table 2.15.9 shows that the total benefit-cost ratio for implementation of the Myall Lakes management actions is 3.9. Benefit-cost ratios above 1 are considered to be positive.

As described in Section 2.15.1.3, the modelling undertaken to develop this WQIP has focussed on the ecological response of the estuary in relation to changes in catchment loads. Recognising that there is a suite of benefits that cannot be accounted for in this approach (including the improvements that occur on individual river reaches), economic analysis of individual management actions was undertaken to partially account for this limitation. The benefit-cost ratios for individual actions in the Myall Lakes Plan are shown in Table 2.15.9.

Table 2.15.9. Myall Lakes WQIP benefit-cost ratio of individual actions.

Program[pt104]	**Benefit-cost ratio**
Remediation actions	
Groundcover management	2.0
Nutrient management (Fertiliser)	4.0
Infrastructure (Dam) management	0.1
Riparian remediation	5.6
Unpaved road remediation	*
Protection actions	
Water Sensitive redevelopment	*
Wetland protection	3.3
Riparian protection	12.2
Water Sensitive Development of Greenfield sites	2.9
Water Sensitive Urban Design protection	3.2
Best management of unpaved roads	*
Improved management of lake use activities	*
Improved pollution control systems / management systems	*
Management support actions	
Adaptive Management Strategy / Ecological monitoring	*
General awareness-raising and business planning	*
Future investigation relating to the Farm Scale Action Plan	*
Total	**3.9**

* The benefit-cost ratio was not calculated for these programs. Refer to Appendix 15 for further information.

This data facilitates consideration of which action is providing the greatest return on investment, as represented by the benefit-cost ratio. Allocation of benefits to each individual action in the WQIP was achieved by estimating the contribution that each action makes to general water quality improvement in the estuary and allocating benefits associated with water quality improvement, accordingly. Non-water quality benefits – including vegetation conservation, wetland benefits and changes to river health – were also allocated to the relevant WQIP action.

The analysis indicates that the majority of Myall Lakes management actions provide a positive return on investment (Table 2.15.9). Riparian protection and riparian remediation provide the greatest return on investment largely because of benefits not associated with the estuary. This return on investment is more than just water quality benefits, and includes benefits such as conservation and river health. While this analysis has shown that actions such as dam remediation have costs that exceed benefits, these actions should not be discounted as a result of the study. A very coarse analysis was undertaken of the water quality benefits associated with protection actions, which may have biased the results for these actions, resulting in a low benefit-cost ratio. While dam rehabilitation did not produce a high benefit-cost ratio, it was still considered an important risk minimisation action, given the impacts recorded from a dam failure at Coomba Bay (Appendix 11). These types of low-probability, high-impact events were not able to be accurately accounted for in the modelling, so the benefits of avoiding these types of impacts are also likely to have been underestimated. It is recommended that a more comprehensive analysis of these actions be undertaken in the future to estimate the benefits associated with these types of actions.